Radio Progress During 1939

THE year 1939 presented an unusual degree of progress in nearly all branches of science. In radio, progress was particularly marked, and the year was probably the outstanding one of the last two decades. The year was unusual in that great progress was effected in all aspects of the art, in the scientific branch, in engineering matters, and in practical public-service innovations.

On the scientific front, progress in investigation of wave propagation was especially noteworthy, and the resulting increased knowledge brought about improvement in the ability to select frequencies most effective in long-distance transmission. Much new knowledge of an immediately useful sort was acquired in the relatively new field of ultra-high-frequency propagation, and the National Bureau of Standards began the service of issuing monthly predictions of maximum usable frequencies.

Many new instrumentalities of much practical use were made available. New tubes and devices for the handling of ultra-high frequencies, noise-measuring instruments, numerous new electronic devices, new insulation materials, and measurements of the hearing capacities of three quarters of a million people, were among the noteworthy items and indicate the wide range of contributions to the field. During the year the National Bureau of Standards began another useful public service by transmitting continuously a radio carrier frequency of 5 megacycles modulated with the standard musical pitch of "A440." This service is of great benefit to the musical and broadcast industries by making possible the pitch standardization of musical instruments.

Three new broadcast services were introduced to the public during the year. These were television, facsimile, and ultra-high-frequency sound broadcasting with frequency-modulated waves. In each of these services several stations began regular program operation and receivers were placed on the market for sale to the public. Any single year witnessing the introduction of one important new public service is noteworthy so that the year 1939 was especially remarkable because it saw the introduction of three important new public services.

In commercial facsimile communication, many improvements in technique were introduced during the year, with consequent great improvement in the quality of picture transmission by radio. In addition, high-quality picture transmission by high-speed cable between New York and London was initiated early in the year.

In the home broadcast-receiver field, the performance in the United States was record-breaking. The number of receiving sets and the number of vacuum tubes manufactured during the year was about 50 per cent greater than in 1938. About 9,000,000 receivers, and 100,000,000 receiving vacuum tubes were produced in the United States. There was a marked increase in the use of lightweight dry-battery-operated portable receivers, radio-phonograph combinations, and attachments for home recording. These items, in total, represent a very substantial increase in the home utilization of radio and its associated instrumentalities.

The foregoing summary is based on the information compiled by the Institute's technical committees and reported by them in the following pages. The summary was prepared by the 1939 Annual Review Committee, the personnel of which follows:

A. F. Van Dyck, Chairman

E. K. Cohan	*H. S. Knowles*
J. H. Dellinger	*E. G. Ports*
W. G. H. Finch	*H. M. Turner*
D. E. Foster	*P. T. Weeks*
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PART I—ELECTROACOUSTICS*

Loud Speakers—Microphones—Electromechanical Devices—Room Acoustics—Measuring Apparatus and Techniques—Speech and Hearing

Loud Speakers

No fundamentally new types of loud speakers were reported during 1939. The moving-coil direct-radiator type continued its domination of radio applications. Improvements were made which extend the frequency range, diminish nonlinear distortion, and improve the spatial distribution at high frequencies.

A horn-type loud-speaker unit utilizing an annular or ring-shaped diaphragm with high flexural stiffness, was made available. The lowest flexural resonant frequency substantially exceeds that of a dome-shaped diaphragm of equal area. The outlet location is so chosen as to maintain uniform radiation resistance up to a relatively high frequency.

A new cellular horn has rigid medial partitions attached to the cell walls through resilient damping material, to stiffen the cell walls, dampen their mechanical modes, and eliminate approximately half the transverse acoustic modes. The total radiation and polar characteristic of a cellular horn depend on the relative transit times of the sound waves through the passages. In this horn the passages are so constructed

* Decimal classification: 621.385.97.

that the transit time is controlled without changing their physical length.

Uniform coverage over a wide horizontal angle was achieved in a single-channel horn.[1] A throat section connects at right angles with a mouth section which subtends a constant horizontal angle and has a suitably chosen vertical flare.

Frequency modulation and television revived interest in inexpensive wide-range loud speakers. Improvements in the design of curvilinear diaphragms and their suspensions made possible the production of several single-diaphragm units[2] meeting these requirements.

Refinements in single-voice-coil, multiple-cone loud speakers were also reported.[3]

Further investigations into nonuniformities of the magnetic field in the air gap of a moving-coil loud speaker were reported[4,5] and good agreement between experimentally determined and calculated values shown.

An experimental study of European output tubes employing loud-speaker loads was reported.[6] Tests were made of pentodes with negative feedback sufficient to provide source resistance and resulting damping equivalent to that for a triode. Under these conditions pentodes proved to be superior as regards power sensitivity, distortion, and effect of reactive components of the normal loud-speaker impedance.

There was made commercially available a compact dual-speaker system which consists of a small direct-radiator high-frequency speaker mounted coaxially within the hollow of the cone of a low-frequency unit. The size and position of the high-frequency unit result in a wide-angle polar response and wide-range reproduction with apparent unit source.

Microphones

No radically new types of microphones appeared during 1939, more attention being paid to applications.

The frequency spectra of impulsive sound sources, when placed in free space, pressure chambers, and exponential horns, were investigated.[7] These sources were used in the calibration of microphones, the results agreeing to within ± 1 decibel with those obtained by conventional means.

Electromechanical Devices

Investigations of the physical properties of piezoelectric crystals were continued. One research[8] measured the elastic, electric, and piezoelectric constants by determining, at low field strengths, the resonant frequency and impedance of vibrating Rochelle salts. It was shown that the lowest resonant frequency of the crystal is considerably below the natural mechanical resonant frequency of the piezoelectric crystal. If piezoelectric stress is assumed proportional to the charge density rather than the potential gradient as was usually assumed, then agreement appears between theory and experiment. Other researches dealt with the specific heat of the crystals to ascertain whether anomalies exist[9,10] but agreement between different investigators is lacking.

An inexpensive radio-phonograph combination incorporating a simplified recording mechanism for home use has been offered by one radio receiver manufacturer. Coated-paper record blanks are used, and recordings can be made from either microphone or radio input with immediate playback through the regular phonograph channel.[11]

Recording on disks for immediate playback continued to be based largely on experience rather than theory, with a fuller appreciation of the many precautions[12] necessary. The effects of pickup, character of track modulation, and ear response on scratch were investigated.[13]

Recording on magnetic tapes received much attention, with continued improvement in convenience and response.[14]

The effect of transient elastic deformation of lateral-cut phonograph-record grooves was investigated[15] from the viewpoints of tracking and distortion.

Studies of piezoelectric crystals as elements of electroacoustic devices were made to determine design characteristics of the crystal and matching amplifier.[16,17]

Room Acoustics

The problems encountered in architectural acoustics are so complex that most of the advances were of an empirical nature. However, the fresh viewpoint of recent theoretical work gave every indication of aiding

[1] "Loudspeaker," *Electronics*, vol. 12, p. 68; December, (1939).
[2] G. W. Fyler and J. A. Worcester, Jr., "A noise-free radio receiver," *Gen. Elec. Rev.*, vol. 42, p. 309; July, (1939).
[3] "Voigt 'light coil twin' loudspeaker," *Wireless World*, vol. 44, p. 223; March 9, (1939).
[4] V. V. Furdeev, N. K. Mikheeva, and B. S. Grigor'ev, "Nonlinear distortion electrodynamic loud speaker," *Izvestiya Elektroprom. Slab. Toka*, no. 2, pp. 25–38; (1939).
[5] W. Reinhard, "Inhomogeneity of the magnetic fields of dynamic loud speaker," *Akust. Zeit.*, vol. 4, pp. 137–141; March, (1939).
[6] A. J. Heins van der Ven, "Output stage distortion," *Wireless Eng.*, vol. 16, pp. 383–390; August, (1939), and vol. 16, pp. 444–452; September, (1939).
[7] W. Weber, "The sound spectra of sparks and pistol shots with reference to their application to electroacoustic measurement technique," *Akust. Zeit.*, vol. 4, pp. 373–391; November, (1939).
[8] W. P. Mason, "A dynamic measurement of the elastic, electric and piezo-electric constants of Rochelle salt," *Phys. Rev.*, vol. 55, pp. 775–789; April 15, (1939).
[9] W. Bantle and P. Scherrer, "Anomaly of the specific heat of potassium dihydrogen phosphate at the upper Curie point," *Nature*, vol. 143, p. 980; June 10, (1939).
[10] A. J. C. Wilson, "The heat capacity of Rochelle salt between $-30°$ and $+30°$ C.," *Phys. Rev.*, vol. 54, pp. 1103–1109; December 15, (1938).
[11] "Recordio," *Radio and Telev. Ret.*, vol. 24, p. 55; October, (1939).
[12] C. J. Lebel, "Disc cutting problems," *Electronics*, vol. 12, pp. 17–19; December, (1939).
[13] M. G. Scroggie, "Gramophone record scratch," *Wireless World*, vol. 46, pp. 3–7; November, (1939).
[14] B. Mueller-Ernesti, "The magnetophone," *Funktech. Monatshefte*, no. 5, pp. 151–154; May, (1939).
[15] F. V. Hunt and J. A. Pierce, "Stylus-groove relations and their influence on phonograph reproducer design." Presented, November, 1939, meeting, Acoustical Society of America, Iowa City, Iowa.
[16] P. Beerwald and H. Keller, "Piezoelectric crystal elements for electroacoustical purposes," *Funktech. Monatshefte*, no. 11, pp. 345–348; November, (1938), and pp. 97–100; April, (1939).
[17] C. Crescini, "Piezoelectricity in acoustics," *Radio e Televisione*, vol. 3, pp. 51–61; January, (1939).

progress by beginning to explain many of the effects encountered in practice.

The room problem received extensive theoretical treatment in which the normal acoustic impedance of the boundaries was used to determine the modes of free vibration.[18,19] The pressure variation in the standing waves between walls, one of which has infinite impedance, gives information applicable to live-end—dead-end studio construction.

Information pertinent to the boundaries was obtained by steady-state transmission measurements[20] between source and receiver in a model room. The width of the resonance curve at the half-intensity points was shown to be a measure of the total absorption for a given mode of vibration.

Methods for the computation of sound-pressure decay were presented for simple configurations of source, treated room, and detector.[21] Results agreed very well with measured decay curves using warble tones and an automatic recorder. An important feature is the weighting of the normal modes of vibration according to their directions.[22]

Isobaric plots of the sound field in model rooms of high wall impedance[23] show the effects of sloping walls and coupled spaces and the existence, in rooms of irregular shape, of well-defined standing-wave patterns.

The use of an enclosure of moderate size to study the decay of isolated normal modes[24] was reported. Good agreement was obtained between damping coefficients obtained from reverberation times and those computed by normal impedance measurements.

A study of the absorption coefficients of materials by a direct measurement of reflection in free space was made,[25] and comparisons with theoretical values and the usual standing-wave method values showed good agreement.

A sound source for space-acoustic measurement was developed providing a plurality of equiamplitude tones[26] spaced equally in frequency over a frequency band. The tones, derived from disk records, have a constant ratio of band width to mean frequency.

More work was done with resonant absorbers consisting of resistive as well as reactive elements.[27] A device using this principle was constructed for determining absorption coefficients by the substitution method.[28]

Measuring Apparatus and Techniques

The technique of square-wave testing,[29] given a great impetus by television, has important application in the testing of electrical and electroacoustic apparatus. There was announced a generator[30] for this purpose, in which the voltage change takes place within 0.001 cycle.

An optical harmonic analyzer was constructed[31] which uses a variable-area recording of the sound to be analyzed. Variable-density masks of the desired harmonics are superimposed on the original and the combination scanned for maximum and minimum light transmission to obtain amplitude and phase.

The German Acoustics Committee made proposals[32] to the International Standardization Association (I.S.A.) regarding specifications for microphone and loud-speaker rating and testing, for an international standard of pitch, and for recording and playback equipment.

The need for a standard of musical pitch has been demonstrated by a series of measurements[33] on "A440" taken during concerts broadcast from four European countries. The average pitch of each of the various groups varied markedly, and small deviations were noted during a performance. The continuous broadcast of "A440" at a carrier frequency of 5 megacycles was inaugurated by the National Bureau of Standards.[34]

Apparatus for producing artificial reverberation was developed. In one type the signal is magnetically recorded on a moving tape from which a number of time-displaced pickup heads feed the energy, through adjustable volume controls, back into the transmission line.[35] In another, delay and decay are obtained by impressing signal-modulated radiant energy from a mercury-vapor source on the phosphor-coated rim of a rotating wheel.[36] A third type utilizes a mechanical transmission line of interconnected helical springs, with various values of impedance and time of trans-

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[19] P. M. Morse, "Transmission of sound inside pipes," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 205–211; October, (1939).

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[21] F. V. Hunt, L. L. Beranek, and D.-Y. Maa, "Analysis of sound decay in rectangular rooms," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 80–94; July, (1939).

[22] D.-Y. Maa, "Distributions of eigentones in a rectangular chamber at low frequency range," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 235–238; January, (1939).

[23] R. H. Bolt, "Normal modes of vibration in room acoustics: Experimental investigations in non-rectangular enclosures," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 184–197; October, (1939).

[24] N. B. Bhatt, "Effect of an absorbing wall on the decay of normal frequencies," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 67–73; July, (1939).

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[26] W. L. Barrow, "The multitone," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 275–279; April, (1939).

[27] W. Willms, "On sound absorption with the aid of damped resonators," *Akust. Zeit.*, vol. 4, pp. 29–32; January, (1939).

[28] K. Schuster and W. Stohr, "Design and properties of an adjustable comparison impedance," *Akust. Zeit.*, vol. 4, pp. 253–260; July, (1939).

[29] G. Swift, "Amplifier testing by means of square waves," *Communications*, vol. 19, pp. 22–26, 52; February, (1939).

[30] L. B. Arguimbau, "A demonstration of audio testing with square waves," *Electronics*, vol. 12, pp. 23–24; December, (1939). (Summary only.)

[31] H. C. Montgomery, "Optical curve analysis," *Bell Lab. Rec.*, vol. 18, pp. 28–30; September, (1939).

[32] "Communication from the German Acoustics Committee," *Akust. Zeit.*, vol. 4, pp. 62–80; January, (1939).

[33] B. van der Pol and C. C. J. Addink, "The pitch of musical instruments and orchestras," *Philips Tech. Rev.*, vol. 4, pp. 205–210; July, (1939).

[34] "WWV schedules," *QST*, vol. 24, p. 25; January, (1940).

[35] S. K. Wolff, "Artificially controlled reverberation," *Jour. Soc. Mot. Pic. Eng.*, vol. 32, pp. 390–397; April, (1939).

[36] P. C. Goldmark and P. S. Hendricks, "Synthetic reverberation," Proc. I.R.E., vol. 27, pp. 747–752; December, (1939).

mission. A moving-coil motor drives the line, and the delayed signal, with its multiple and nonuniform reflections, is picked up by a piezoelectric receiver.

For investigating microphone distortion a standing-wave resonance system was described[37] that produces a high-pressure sound field in which a given harmonic has been eliminated. It consists of a long, heavy-walled iron pipe with a dynamic loud speaker at one end and a movable iron piston at the other. Harmonic attenuation factors of 68 to 1 and higher (on a pressure basis) are obtained, hence the sound field is free of the unwanted harmonic to within a few hundredths of one per cent with three per cent harmonic in the speaker-input voltage.

Speech and Hearing

Additional data concerning speech characteristics became available. A study of sound pressure in the neighborhood of a speaker's head[38] revealed that equalization of microphone circuits to correct for this variation is unnecessary for angles between +90 and −45 degrees in the vertical plane and up to horizontal angles of 75 degrees. Further information permits equalization at extreme angles. These data permitted the calculation of the average spectra of voice power for men and women.[39,40]

Important additions to our statistical knowledge of hearing ability resulted from measurements on a large representative sample of people obtained under controlled conditions.[41,42] In one study, tests for the acuity of hearing for both pure tones and spoken words were made on half a million persons at the New York and the San Francisco World's Fairs.[43,44] Preliminary conclusions indicate hearing deficiencies sufficiently common to warrant their consideration in the design of reproducing equipment.

Threshold variations in the frequency band width which the ear just perceives in speech transmission were reported.[45] By progressively changing the cutoff frequency of low- or high-pass filters, the ear distinguishes approximately 30 stages of band-width variation; only some of these are approximately logarithmic frequency increments.

A binaural hearing aid has been developed employing an artificial head containing two microphones at the ear positions. The transmission of each channel is adjusted to the individual ear.[46] Another hearing aid has been introduced using an improved bone-conduction receiver[47] with a new type of spring-suspension design giving increased efficiency, extended frequency response, and a sharp high-frequency cutoff.

The asymmetry of the wave form of masculine speech has been used to permit "150 per cent modulation" by so connecting the microphone to the transmitter as to make the larger peaks correspond to positive modulation.[48]

Basic studies of speech sounds led to the construction of devices for synthesizing speech. In one instance, an instrument analyzes the pitch and spectral distribution of a speaker's words and by means of low-frequency control currents containing none of the original frequencies, synthesizes speech from a combination of buzz- and hiss-type sounds.[49,50] Another version of this instrument was constructed for demonstration purposes in which arbitrary speech sounds were obtained from the same components as above but controlled manually by a skilled operator.[51]

As a factor in stimulating audience reaction in the theater, increased use is being made of supplementary sound controlled by electronic means.[52] Experiments were carried on and methods developed by which the entire frequency and intensity range to which the ear responds may be used to establish locale, atmosphere, and mood.

A number of developments reported during 1938 had their first formal publication in 1939.[53–56]

This report was prepared by the 1939 Technical Committee on Electroacoustics of the Institute of Radio Engineers, the personnel of which follows:

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[37] W. D. Phelps, "A sound source for investigating microphone distortion," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 219–221; October, (1939).

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[39] H. K. Dunn and S. D. White, "Statistical measurements on conversational speech," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 278–288; January, (1940).

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[45] E. Schafer, "The audibility of variations in frequency band in speech transmission," *Elek. Nach. Tech.*, vol. 15, pp. 237–240; August, (1938).

[46] K. de Boer and R. Vermeulen, "On improvement of defective hearing," *Philips Tech. Rev.*, (English Edition), vol. 4, pp. 316–320; November, (1939).

[47] M. S. Hawley, "The 710A bone-conduction receiver," *Bell Lab. Rec.*, vol. 18, pp. 12–14; September, (1939).

[48] J. L. Hathaway, "Effect of microphone polarity on percentage modulation," *Electronics*, vol. 12, pp. 28–29, 51; October, (1939).

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[52] H. Burris-Mayer, "Sound in the theatre," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 346–351; January, (1940).

[53] H. F. Olson, "Multiple coil, multiple cone loud speakers," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 305–312; April, (1939). (See reference 7 in 1938 report.)

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PART II—ELECTRONICS*

Cathode-Ray and Television Tubes—Ultra-High-Frequency Tubes—Receiving Tubes—Transmitting Tubes—Gas Tubes—Photoelectric Devices

Cathode-Ray and Television Tubes

Television pickup tubes of the iconoscope type were made more sensitive and with a more sharply focused beam. A tube which attains high storage efficiency and freedom from spurious signals through the use of a scanning beam composed of low-velocity electrons was announced.[1,2] Further improvements in tubes which use a picture-storage grid to control the passage of scanning electrons[3] and in tubes which use secondary-emission amplification of an electron image,[4,5] took place. Theoretical work showed the possibility of attaining a large increase in pickup-tube sensitivity by using repeated multiplication of an electron image of the scene to be transmitted.[6] New forms of pickup tubes which operate with beams of high-velocity electrons[4] or make use of change in capacitance resulting from illumination were developed.[7]

Direct-viewing television picture tubes with larger deflection angles than heretofore were made available commercially. These are shorter tubes and have better spot-size characteristics at the cost of increased scanning-power requirements and greater susceptibility to spot distortion at the picture edge. Wider use is being made of magnetic lenses for focusing the beam.[8] A method of avoiding the ion-spot discoloration of the screen by separation of the ions from the electrons by means of a constant transverse magnetic deflecting field appeared.[9] The possibility of increasing the beam voltage without proportionately decreasing the deflection sensitivity by means of beam acceleration after deflection received both theoretical and experimental study,[10,11] Such tubes have been made available. Geometrical distortion of the picture shape resulting from bulb curvature has been avoided in some tubes by using a flat screen.[9] In one type of tube the screen has a rectangular shape enabling more of the screen area to be used for the picture.[12] The design of magnetic-deflection coils has received attention.[13]

A projected picture, 12 by 15 feet, having improved brightness was demonstrated to motion-picture audiences.[14] A projection tube in which the fluorescent screen is deposited on the inner surface of a metal wall, the outer surface being exposed for direct air-cooling,[12] was developed for use with home television receivers. Theoretical and experimental investigations demonstrated the possibility of using a cathode-ray beam to control the light transmission of a screen.[15,16] In one form of tube, zinc-blende crystals are flooded with polarized light, and the transmitted light is focused on the projection screen.

Published investigations in the field of electron optics include a mathematical analysis of the electron-lens field,[17] calculations for the focusing of high-velocity electrons,[18,19] analysis of the acceleration of electrons after deflection,[11] and calculation of aperture errors.[20]

Continued analyses of the possibilities and limitations of the electron microscope have led to published results dealing with chromatic errors[21,22] and resolving power.[23,24] The raster or scanning-type[25] and the shadow-type[26] microscope were described and their relative merits discussed.[27]

* Decimal classification: R330×621.375.1.

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[7] M. Knoll and R. Thiele, "Capacity-modulated cathode-ray scanning tubes," *Teleg.- Fern.- und Funk-Tech.*, (Supplement), vol. 27, pp. 538–540; November, (1938).

[8] "The wireless exhibition, 1939; A technical survey," *Wireless Eng.*, vol. 16, p. 510; October, (1939).

[9] "Philco demonstrates improved picture tube," *Radio and Tel. Weekly*, vol. 47, p. 6; June 21, (1939).

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[11] Rogowski and Thielen, "Post-acceleration in cathode-ray tubes," *Arch. für. Elektrotech.*, vol. 33, pp. 411–417; June 14, (1939).

[12] R. Moller and G. Schubert, "The further development of our receiver and picture-viewing devices for 1939," *Fernseh A. G.*, vol. 1, pp. 153–161; August, (1939).

[13] H. Bahring, "The deflection of the electron ray in the cathode-ray tube by magnetic fields produced by coils," *Fernseh A. G.*, vol. 1, pp. 15–19; December, (1938).

[14] "Baird cinema equipment," *Television*, vol. 12, p. 199; April, (1939).

[15] M. von Ardenne, "Methods and arrangements for the application of the 'storage' principle to television reception," *Teleg.- Fern.- und Funk-Tech.*, (Supplement), vol. 27, pp. 518–524; November, (1938).

[16] M. von Ardenne, "Storage methods in television reception," *Television*, vol. 12, pp. 67–72; February, (1939).

[17] A. Boni, "Calculation by successive approximations of the electrostatic field of a cylindrical system," *Radio e Televisione*, vol. 3, pp. 335–346; May, (1939).

[18] Cutte, "The focusing of electrons possessing high velocities and the general properties of centered systems in relativistic mechanics," *Rev. Gen. de l'Élec.*, vol. 45, pp. 675–677; May 20, (1939).

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[26] Boersch, "The shadow microscope, a new electron super-microscope," *Naturwiss.*, vol. 27, p. 418; June 9, (1939).

[27] M. von Ardenne, "Efficiency of the electron shadow microscope," *Naturwiss.*, vol. 27, pp. 485–496; July 14, (1939).

Work on oscillograph tubes continued. Tube development included the use of multiphase fields[28] for ultra-high-frequency waves and the design of multibeam tubes.[29] Beam-deflection theory relating to the deflecting-plate region has been refined to include effects of stray fields and their expression in terms of an equivalent uniform deflecting field.[30] Calculations of the optimum shaping of the deflecting plates for highest possible sensitivity were contributed.[31] An investigation was made of the cutoff phenomenon with electrostatic-deflection tubes as applied to frequencies at which the transit time is significant.[32]

Luminescent materials of improved properties were developed. A useful comprehensive survey of the state of the art has been published.[33]

Ultra-High-Frequency Tubes

The past year witnessed the publication of a number of papers on some new types of ultra-high-frequency electronic devices which are characterized by the use of electron beams and by unconventional input and output circuits.

Several of the reported developments of electronic devices, whose operation depends essentially on impressing a velocity variation on an electron stream, are closely related to some earlier work,[34] which appeared to receive scant recognition at the time of its publication.

Of such devices those variously referred to as "Klystrons" or as "Velocity-Modulation" tubes, or as using "Phase Focusing" form one class. In this class as a result of velocity variation, faster electrons tend to overtake slower electrons which preceded them, and the electrons subsequently become grouped when the stream is projected through a field-free region. After grouping has occurred, the stream is sent through an output region and may finally be collected at a relatively low velocity.

Whereas the earlier work was restricted, in that the input and output regions were interconnected, the more recent devices are often constructed so as to isolate the input and output portions of the structures. One device[35] described during the year employs input and output circuits in the form of electrically resonant cavities. More exact formulas for the resonant frequencies of such circuits have been developed and the coupling problems have been considered.[36–41]

Another device[42] employs electrodes in the form of cylinders whose lengths correspond to an electron transit time of an odd number of half periods at the operating frequency. Each of these electrodes doubles the number of points at which the circuit interacts with the electron stream. This is said to increase the over-all transadmittance of the device by a factor of approximately four.

A second general class of devices obtain electron grouping from velocity variations by the use of deflecting or reflecting fields to separate fast- and slow-moving electrons.[42]

While no detailed experimental results have been published, satisfactory operation of an amplifier of the velocity-variation type was described for frequencies as high as 6000 megacycles (5 centimeters), with an input conductance as low as 20 micromhos. Oscillators with outputs of 300 watts at about 1000 megacycles (30 centimeters) were also reported.[43]

A related device described during the year,[44] employed an electron beam and an electrically resonant cavity for its output circuit but depends upon the conventional grid for grouping of the electrons in the stream. An output of 110 watts with an efficiency of 35 per cent at 450 megacycles was reported, the required driving power being 10 watts. In a 500-megacycle tube with an output of 10 watts, the use of an improved focusing scheme has been disclosed and the operation of the device as a wide-band amplifier described.[45]

The general theory of electron grouping received considerable attention.[46–53] The analyses have in general taken two forms: one[42,46,47,52,53] in which the mutual

[28] H. E. Hollmann, "The deflection of cathode rays in multiphase fields," *Elek. Nach. Tech.*, vol. 15, pp. 336–341; November, (1938).

[29] A. Bigalke, "Four-beam electron tube of high writing velocity," *Arch. für Elektrotech.*, vol. 33, pp. 108–110; February 15, (1939).

[30] A. Thoma, "New investigations on cathode-ray oscillographs," *Funktech. Monatshefte*, no. 10, pp. 313–316; October, (1938); no. 11, pp. 329–331; November, (1938).

[31] Flechsig, "Electrostatic deflection in cathode-ray tubes with nonparallel deflecting plates," *Elek. Tech. Zeit.*, vol. 60, p. 798, July, (1939). (Summary only.)

[32] Hollmann, "Ultradynamic overcontrol of cathode-ray tubes," *Hochfrequenz. und Elektroakustik*, vol. 52, pp. 125–129; October, (1938).

[33] H. W. Levereng and F. Seitz, "Luminescent materials," *Jour. App. Phys.*, vol. 10, pp. 479–493; July, (1939).

[34] Arsenjewa-Heil and Heil, "A new method of producing short undamped waves of great intensity," *Zeit. für Phys.*, vol. 95, pp. 752–762; July 12, (1935).

[35] R. H. Varian and S. F. Varian, "A high-frequency oscillator and amplifier," *Jour. App. Phys.*, vol. 10, pp. 321–327; May, (1939).

[36] W. W. Hansen, "On the resonant frequency of closed concentric lines," *Jour. App. Phys.*, vol. 10, pp. 38–45; January, (1939).

[37] W. W. Hansen and R. D. Richtmyer, "On resonators suitable for Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 189–199; March, (1939).

[38] F. Borgnis, "Electromagnetic natural vibrations of dielectric spaces," *Ann. der Phys.*, vol. 35, pp. 359–384; June 11, (1939).

[39] R. D. Richtmyer, "Dielectric resonators," *Jour. App. Phys.*, vol. 10, pp. 391–398; June, (1939).

[40] M. Jouguet, "On the natural electromagnetic oscillations of a cavity," *Compt. Rend.*, vol. 209, pp. 203–204; July 24, (1939).

[41] A. G. Clavier, "Theoretical relationships of dielectric guides," *Elec. Comm.*, vol. 17, pp. 276–290; January, (1939).

[42] W. C. Hahn and G. F. Metcalf, "Velocity-modulated tubes," Proc. I.R.E., vol. 27, pp. 106–116; February, (1939).

[43] "Cathode-ray amplifier tubes," *Electronics*, vol. 12, pp. 9–11; April, (1939).

[44] A. V. Haeff, "Ultra-high-frequency power amplifier of novel design," *Electronics*, vol. 12, pp. 30–32; February, (1939).

[45] A. V. Haeff and L. S. Nergaard, "A wide-band inductive-output amplifier," Proc. I.R.E., vol. 27, p. 610; September, (1939) (Abstract only.) (See this issue.)

[46] L. Mayer, "Experimental demonstration of phase focusing," *Zeit. für Tech. Phys.*, vol. 20, pp. 38–42; no 2 (1939).

[47] W. C. Hahn, "Wave energy and transconductance of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 497–502; November, (1939).

[48] Simon Ramo, "The electronic-wave theory of velocity-modulation tubes," Proc. I.R.E., vol., 27, pp. 757–763; December, (1939).

repulsion effects between electrons are disregarded or at best are included only as a second-order correction, but which is applicable to large and small signals; and a second[50–52] in which space-charge forces are considered but in such a way as to limit the analysis to small signals. The large-signal theory indicates that a theoretical output efficiency of 58 per cent is possible.[52]

The problems associated with the formation and use of the electron beams required by the above devices received independent study.[54,55] Other theoretical advances included some progress in evaluating the high-frequency effects of double-valued electron velocities.[56]

The successful operation of a diode oscillator at 3000 megacycles (10 centimeters) was reported.[57]

Of the more conventional types of vacuum tubes[58,59] a 20-kilowatt tetrode amplifier suitable for use at frequencies up to 120 megacycles (2.5 meters) was described.[58] In order to minimize coupling between the input and output circuits the tube is of a special double-ended construction. A squirrel-cage screen is supported at both ends by radial flanges which can be connected to external shields so as to enclose the anode and the output circuit completely.

The flood of papers on tubes of the magnetron types which has been evident for several years continued. A magnetron has been described[60] which delivers 20 watts at 3750 megacycles (8 centimeters) with an efficiency of 20 per cent. Workers in Japan[61] reported outputs of 10 to 80 watts in the frequency range from 1765 to 3000 megacycles (17 to 10 centimeters) and efficiencies up to 88 per cent.

Receiving Tubes

The year continued the trend of recent years in refining methods of analysis and measurement and in furthering an understanding of basic phenomena.

Contributions to knowledge of the behavior of metals, both clean and coated, in relation to electron emission included (1) a useful up-to-date survey[62] of physical properties of oxide-coated cathodes and papers on the theories concerning their behavior;[63,64] (2) an analysis of the decay with time of temperature-limited thermionic emission from oxide-coated cathodes, with discussion as to whether it is a volume or a surface effect;[65] (3) experimental and theoretical studies of the relation between secondary electron emission and the energies of primary electrons;[66] and (4) accumulation of further data and greater perfection of the physical picture of electron behavior while within and escaping from metals, in relation to electronic energy levels and surface effects such as work functions, contact differences of potential, and surface potential structure.[67–72]

A number of workers continued investigations of noise phenomena. Flicker effect for the frequency range 40 to 20,000 cycles was discussed;[73] it appears that the mean-square noise current varies inversely with frequency rather than inversely with the square of the frequency as previously reported. Present knowledge of the tube noise was reviewed and general agreement between American, English, and German workers reported.[74,75]

Tube noise in frequency converters was found to be the average noise over an oscillator cycle.[76] The results were confirmed and applied to several types of frequency-converters for television use.[77]

[49] G. Jobst, "Influence and control of the variable density of electron currents in tubes and the use of this phenomenon for generating short-wave oscillations by the impulse method," *Telefunken Hausmitteilungen*, vol. 20, pp. 84–96; July, (1939).

[50] W. C. Hahn, "Small signal theory of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 258–270; June, (1939).

[51] Simon Ramo, "Space charge and field waves in an electron beam," *Phys. Rev.*, vol. 56, pp. 276–283; August 1, (1939).

[52] D. L. Webster, "Cathode-ray bunching," *Jour. App. Phys.*, vol. 10, pp. 501–508; July, (1939).

[53] D. L. Webster, "Theory of Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 864–872; December, (1939).

[54] A. V. Haeff, "Space-charge effects in electron beams," Proc. I.R.E., vol. 27, pp. 586–602; September, (1939).

[55] J. R. Pierce, "Limiting current densities in electron beams," *Jour. App. Phys.*, vol. 10, pp. 715–724; October, (1939).

[56] W. Kleinsteuber, "The inference of space charge in planar braking-field tubes," *Hochfrequenz. und Elektroakustik*, vol. 53, pp. 199–213; June, (1939).

[57] F. B. Llewellyn and A. E. Bowen, "Production of ultra-high-frequency oscillations by means of diodes," *Bell. Sys. Tech. Jour.*, vol. 18, pp. 280–291; April, (1939).

[58] A. V. Haeff, L. S. Nergaard, W. G. Wagener, P. D. Zottu, R. B. Ayer, and H. E. Gihring, "Development of a 20-kilowatt ultra-high-frequency tetrode," Proc. I.R.E., vol. 27, pp. 610–611; September, (1939). (Summary only.)

[59] A. V. Haeff, "Effect of electron transit time on efficiency of a power amplifier," *RCA Rev.*, vol. 4, pp. 114–122; July, (1939).

[60] E. G. Linder, "The anode-tank-circuit magnetron," Proc. I.R.E., vol. 27, pp. 732–738; November, (1939).

[61] S. Uda, M. Isida, and S. Shoji, "High-efficiency sentron," *Electrotech. Jour.* (Tokyo), vol. 2, p. 291; December, (1938).

[62] J. P. Blewett, "The properties of oxide-coated cathodes," *Jour. App. Phys.*, vol. 10, pp. 668–670; October, and pp. 831–848; December, (1939).

[63] C. H. Prescott, Jr., and James Morrison, "The oxide-coated filament: The relation between thermionic emission and the content of free alkaline-earth metals," *Jour. Amer. Chem. Soc.*, vol. 60, pp. 3047–3053; December, (1938).

[64] C. H. Prescott, Jr., and James Morrison, "The true-temperature scale of an oxide-coated filament," *Rev. Sci. Inst.*, vol. 10, pp. 36–38; January, (1939).

[65] J. P. Blewett, "Time changes in emission from oxide-coated cathodes," *Phys. Rev.*, vol. 55, pp. 713–717; April 15, (1939).

[66] D. E. Wooldridge, "Theory of secondary emission," *Phys. Rev.*, vol. 56, pp. 562–578; September 15, (1939).

[67] R. L. E. Seifert and T. E. Phipps, "Evidence of a periodic deviation from the Schottky line, I," *Phys. Rev.*, vol. 56, pp. 652–663; October 1, (1939).

[68] D. Turnbull and T. E. Phipps, "Evidence of a periodic deviation from the Schottky line, II," *Phys. Rev.*, vol. 56, pp. 663–666; October 1, (1939).

[69] H. M. Mott-Smith, "Periodic deviation from the Schottky line," *Phys. Rev.*, vol. 56, pp. 668–669; October 1, (1939).

[70] W. Shockley, "On the surface states associated with a periodic potential," *Phys. Rev.*, vol. 56, pp. 317–323; August 15, (1939).

[71] E. V. Condon, "Notes on the external photoelectric effect of semiconductors," *Phys. Rev.*, vol. 54, p. 1089; December 15, (1938).

[72] P. Anderson, "Contact difference of potential between barium and magnesium," *Phys. Rev.*, vol. 54, p. 753; November 1, (1938).

[73] W. Graffunder, "Valve noise at low frequency," *Telefunken-Röhre*, no. 15, pp. 41–63; April, (1939).

[74] F. B. Llewellyn, "Report on noise in vacuum tubes," *U.R.S.I. Proc. of 1938 General Assembly, Venice and Rome*, vol. 5, pp. 8–12.

[75] E. B. Moullin, "Report on the present state of knowledge concerning fluctuation voltages in electrical networks and thermionic tubes," *U.R.S.I. Proc. of 1938 General Assembly, Venice and Rome*, vol. 5, pp. 12–17.

[76] E. Lukacs, F. Preisach, and Z. Szepcsi, "Noise in frequency changer valves (Letter)," *Wireless Eng.*, vol. 15, p. 611; November, (1938).

[77] E. W. Herold, "Superheterodyne converter system considerations in television receivers," *RCA Rev.*, vol. 4, pp. 324–327; January, (1940).

Experiments indicate that for normal-incident primary electrons the decrease of secondary emission with increased atomic volume of the target results from the absorption of secondary electrons. For slow (10-volt) primary electrons, the more positive electropositive metals produce the greater secondary emission.[78]

The use of a conventional receiving tube as a negative-transconductance oscillator was described.[79] Theory and supporting measurements of input grid admittance as affected by electron path were reported for pentodes, heptodes, and octodes.[80]

Measurements of vacuum-tube properties were discussed in two papers covering (1) output-stage distortion[81] and (2) a precision method for measuring mutual conductance.[82]

Consideration was given to more-accurate calculation of the constants and space current of triodes with close spacings between the grid and the cathode. Approximate corrections for the effect of initial velocity of emission for the cathode are included.[83]

The use of spectrographic methods for the analysis of the chemical constitution of metals and of various gases and vapors was greatly extended during the past year. Such methods are now of increasing importance in comparative metallurgical analysis and in production control.[84] Spectrographic methods for the measurement of gas temperatures were also improved.

There appeared two papers on design characteristics, one on tetrode and pentode output tubes[85] and the other on the input conductance of radio-frequency tubes.[86]

[78] H. Bruining and J. H. DeBoer, "Secondary electron emission," (in 5 parts) *Physica:* "Part I. Secondary emission of metals," vol. 5, p. 17; January, (1938). "Part II. Absorption of secondary electrons," vol. 5, p. 901; November, (1938). "Part III. Secondary electron emission caused by bombardment with slow primary electrons," vol. 5, p. 913; November, (1938). "Part IV. Compounds with a high capacity for secondary electron emission," vol. 6, p. 823; August, (1939). "Part V. The mechanism of secondary electron emission," vol. 6, p. 834; August, (1939).

[79] Cledo Brunetti, "The transitron oscillator," PROC. I.R.E., vol., 27, pp. 88–94; February, (1939).

[80] M. J. O. Strutt and A. van der Ziel, "Some dynamic measurements of electronic motion in multigrid valves," PROC. I.R.E., vol. 27, pp. 218–225; March, (1939).

[81] A. J. H. van der Ven, "Output-stage distortion: Some measurements on different types of output valves," *Wireless Eng.*, vol. 16, pp. 383–390; August; pp. 444–452; September, (1939).

[82] N. F. Astbury, "A precision method for the measurement of the mutual conductance of thermionic valves," *Jour. Sci. Inst.*, vol. 16, pp. 269–272; August, (1939).

[83] J. H. Fremlin, "Calculation of triode constants," *Elec. Comm.*, vol. 18, pp. 33–49; July, (1939); also *Phil. Mag.*, vol. 27, pp. 709–741; June, (1939).

[84] Symposium on spectroscopy, *Jour. App. Phys.*, vol. 10, November, (1939). W. F. Meggers, "Spectroscopic apparatus," pp. 734–740; R. A. Sawyer, "Qualitative and quantitative chemical analysis by line emission spectra," pp. 741–750; W. R. Brode, "Absorption spectra as applied to molecular identification and analysis," pp. 751–759; G. R. Harrison, "Compilations of spectroscopic data," pp. 760–767; H. M. Randall, "Infra-red spectra—observation and uses," pp. 768–779; and G. H. Dieke, "Molecular emission spectra," pp. 780–799.

[85] J. L. H. Jonker, "Pentode and tetrode output valves," *Wireless Eng.*, vol. 16, pp. 274–286; June; pp. 344–349; July, (1939).

[86] George Grammer, "Input resistance of r. f. receiving tubes: Effect on circuit gain and selectivity at high frequencies," *QST*, vol. 23, pp. 41–43, 90; May, (1939).

The trend, noted in previous years, toward an increase in the number of tube types continued. This increase was produced, in part, by the demand for high-voltage-heater tubes for use in alternating-current—direct-current receivers. Other factors, such as reduction in envelope size, new basing arrangements, and new constructions also contributed. A number of new tubes designed for heater operation at 150 milliamperes and voltages ranging from 12 to 70 volts were introduced to eliminate the need for line-resistor cords or ballast tubes in alternating-current—direct-current receivers. Several tubes having 117-volt heaters were introduced to simplify the design of dual-purpose portable sets suitable for operation from a power line or a self-contained dry-battery supply. For small dry-battery sets a line of miniature tubes was introduced featuring conventional electrode structures in small envelopes and improved performance with 45-volt batteries. Their short over-all length, two inches, is made possible by "button-base" construction.[87]

A current movement to reduce the number of receiving-tube types began late in the year. It is further described in the report on radio receivers.[88]

Transmitting Tubes

The most-important advances in the field of large high-vacuum tubes during the year were in development of tubes suitable for very high frequencies. Many of these tubes are described in the section on ultra-high-frequency tubes although in the somewhat lower frequency range, advances also were made.[58,89,90,91] Particular mention may be made of a 20-kilowatt ultra-high-frequency tetrode.[58] The British[90] reported a sealed-off tube having a plate dissipation of 150 kilowatts, which delivered a peak power of 200 kilowatts at 13 meters.

There is noted a growing tendency toward air-cooling of large tubes.[89,92,93] Other advances were concerned largely with mechanical details.[94] A comprehensive survey of the construction, testing, and operation of large high-vacuum tubes, not included in the previous report, appeared in 1938.[95] The development

[87] K. G. Pucklin, "Miniature battery tubes," *Electronics*, vol. 12, pp. 27–28; November, (1939).

[88] "Radio progress during 1939—Part V—Radio receivers," PROC. I.R.E., this issue, page 119.

[89] Tj. Douma and P. Zijlstra, "Recording the characteristics of transmitting valves," *Philips Tech. Rev.*, vol. 4, pp. 56–60; February, (1939).

[90] E. Green and L. T. Moody, "100-kilowatt short-wave broadcasting transmitter type SWB-14 and 18," *Marconi Rev.*, no. 74, pp. 1–23; July–September, (1939).

[91] "New multi-purpose 357A operates at full ratings up to 100 megacycles," *Pick-ups*, pp. 16–34, July, (1939).

[92] M. Van der Beck, "Air-cooled transmitting valves," *Philips Tech. Rev.*, vol. 4, pp. 121–128; May, (1939).

[93] P. G. Cath, "A new principle of construction for radio valves," *Philips Tech. Rev.*, vol. 4, pp. 162–166; June, (1939).

[94] "200 kilowatt valves with replaceable filaments," *Gen. Elec. Rev.*, vol. 32, p. 369; August, (1939).

[95] J. Bell, J. W. Davies, and B. S. Gossling, "High power valves: Construction, testing, operation," *Jour. I.E.E.* (London), vol. 83, pp. 176–198; August, (1938); *Proc. Wireless Section*, vol. 13, p. 177; September, (1938).

of high-power tubes in the United States was curtailed by the present regulatory limitation on the power of broadcast stations.

Gas Tubes

Continued progress was made in the application of cold-cathode tubes[96] and magnetically controlled thyratrons.[97,98]

A new type of oxide-coated cathode for use in gas tubes was described.[99] This cathode consists of a central porous tubular filament filled with activating material and surrounded by vanes whose active coating surface is continuously replenished during life by evaporation from the central reservoir. Such cathodes appear to offer the possibility of extraordinarily long life.

Photoelectric Devices

Compared with previous years, there was a marked increase in the manufacture and use of photoelectric devices, but outstanding developments in new devices and tubes have not been apparent. A new tube employing rubidium[100] is now available, and improvements in design and construction were incorporated in many existing types. Removal of other sources of supply stimulated the manufacture in the United States of barrier-layer photocells. It is reported that cells with characteristics superior to imported units are now available from domestic production. A device for the rapid checking of the spectral sensitivity of phototubes and television pickup tubes was described,[101] and results indicate that it should be useful in production tests for uniformity.

There was a continued and widened use of photoelectric devices in varied applications. One novel application[102,103] at the New York World's Fair was in an exhibit at which the visitor rode along a 0.3-mile diorama representing "the world of tomorrow." A film-recorded description of the exhibit was picked up by a battery of 150 phototubes, each feeding an amplifier channel in such phase that the visitor heard from his own loud speaker a description of the scene immediately before him.

Substantiation of the work on thallium-sulphide surfaces,[104] mentioned last year, was reported. Several papers appeared[105,106,107] on the cause of time-lag phenomena in gas-filled phototubes. These indicate that the time lag can be traced to (1) transit time for the passage of positive ions in the discharge to the cathode and (2) transit time of metastable atoms also formed in the discharge.

Work on electron multipliers continued[108] although published reports on the subject are limited.

A number of developments reported during 1938 had their first formal publication in 1939.[109–114]

This report was prepared by the 1939 Technical Committee on Electronics of the Institute of Radio Engineers, the personnel of which follows:

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[96] S. B. Ingram, "Cold-cathode gas-filled tubes as circuit elements," *Elec. Eng.*, vol. 58, pp. 342–346; July, (1939).

[97] W. P. Overbeck, "The Permatron—A magnetically controlled industrial tube," *Elec. Eng.*, vol. 58, pp. 224–228; May, (1939).

[98] W. P. Overbeck, "The Permatron and its application in industry," *Electronics*, vol. 12, pp. 25–28; April, (1939).

[99] A. W. Hull, "The dispenser cathode—A new type of thermionic cathode for gaseous discharge tubes," *Phys. Rev.*, vol. 56, pp. 86–93; July 1, (1939).

[100] A. M. Glover, "Spectral response of phototubes to new illuminants," *Electronics*, vol. 21, p. 20; December, (1939). (Abstract only.)

[101] T. B. Perkins, "Automatic spectral-sensitivity curve tracer," *Jour. Opt. Soc. Amer.*, vol. 29, pp. 226–234; June, (1939).

[102] James Dunlop and W. T. White, "An armchair spectator conveyer-guide," *Elec. Eng.*, vol. 58, pp. 509–514; December, (1939).

[103] S. T. Stanton, F. R. Marion, D. V. Waters, "Polyrhetor," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 485–501; November, (1939).

[104] F. C. Nix and A. W. Treptow, "Thallous sulphide photo-e.m.f. cell," *Jour. Opt. Soc. Amer.*, vol. 29, pp. 457–462; November, (1939).

[105] A. A. Kruithof, "Time-lag phenomena in gas-filled photoelectric cells," *Philips Tech. Rev.*, vol. 4, pp. 48–55; February, (1939).

[106] W. S. Huxford, "Townsend ionisation coefficients in Cs-Ag-O phototubes filled with argon," *Phys. Rev.*, vol. 55, pp. 754–762; April 15, (1939).

[107] R. W. Engstrom, "Time-lag analysis of Townsend discharge with activated caesium electrodes," *Phys. Rev.*, vol. 57, p. 73; January 1, (1940).

[108] J. S. Allen, "Detection of single positive ions, electrons, and photons by a secondary electron multiplier," *Phys. Rev.*, vol. 55, pp. 966–971; May 15, (1939).

[109] R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of the iconoscope," Proc. I.R.E., vol. 27, pp. 535–540; September, (1939). (See reference 1 in 1938 report.)

[110] Harley Iams, G. A. Morton, and V. K. Zworykin, "The image iconoscope," Proc. I.R.E., vol. 27, pp. 541–547; September, (1939). (See reference 2 in 1938 report.)

[111] C. Larson and B. C. Gardner, "The image dissector," *Electronics*, vol. 12, pp. 24–27, 50; October, (1939). (See reference 4 in 1938 report.)

[112] V. K. Zworykin and J. A. Rajchman, "The electrostatic electron multiplier," Proc. I.R.E., vol. 27, pp. 558–566; September, (1939). (See references 13 and 68 in 1938 report.)

[113] R. R. Law, "Contrast in kinescopes," Proc. I.R.E., vol. 27, pp. 511–524; August, (1939). (See reference 17 in 1938 report.)

[114] A. P. Kauzmann, "New amplifier receiving tubes," *RCA Rev.*, vol. 3, pp. 271–289; January, (1939). (See references 25 and 62 in 1938 report.)

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PART III—WAVE PROPAGATION*

General—Medium Frequencies—High Frequencies—Ultra-High Frequencies

A remarkable aspect of progress was the development of formulas for the calculation of field intensities which are valid for both low and ultra-high frequencies, and in fact for ground-wave propagation at all frequencies. The work of recent years on ultra-high frequencies has led to this advance in understanding of the propagation of radio waves at all frequencies.

The theoretical formulas for ground-wave calculation were brought[1,2] to a new stage of accuracy. Some[3] of the results of these studies were given in graphical form, for a number of frequencies and ground conductivities and for transmitter and receiver on the ground. These and previous studies were for vertically polarized waves. A theoretical solution[4] for the propagation of horizontally polarized waves appeared; it showed that the values of the ground constants are of much less importance for horizontally than for vertically polarized waves.

While basic formulas of sufficient accuracy thus became available for the calculation of ground-wave intensities, there still remained at the end of the year the considerable task of interpreting and formulating them in simple form for engineering purposes. It is probable that the calculation of instantaneous ground-wave intensity over great distances never can be highly exact because there is one factor, atmospheric refraction, which varies unpredictably.

Increased knowledge of the ionosphere led to increased ability to select frequencies for long-distance transmission. Starting in March, monthly predictions of maximum usable frequencies became available.[5]

Calculation of the ionization in the ionospheric layers depends upon a factor called the Lorentz polarization term whose value has not yet been determined. Experimental and theoretical studies[6–11] indicated that its value is zero for the E region and that its effect upon radio propagation in the F region may be so small that it would be difficult to determine by experiment whether its value is $\frac{1}{3}$ or zero.

The important rôle of ionospheric absorption in radio wave propagation has been increasingly recognized, particularly the effects[12–15] of low-layer absorption at low radio frequencies. The new tool provided for the study of such absorption by the discovery in 1935 of the sudden ionospheric disturbance and its solar origin has stimulated investigations of absorption during such disturbances.[16–21] Knowledge of this effect

* Decimal classification: R113.7.

[1] B. van der Pol and H. Bremmer, "Further note on the propagation of radio waves over a finitely conducting spherical earth," *Phil. Mag.*, vol. 27, pp. 261–275; March, (1939).

[2] G. Millington, "The diffraction of wireless waves around the earth," *Phil. Mag.*, vol. 27, pp. 517–542; May, (1939).

[3] B. van der Pol and H. Bremmer, "The propagation of wireless waves waves around the earth," *Philips Tech. Rev.*, vol. 4, pp. 245–253; September, (1939).

[4] M. C. Gray, "Diffraction and refraction of a horizontally polarized electromagnetic wave over a spherical earth," *Phil. Mag.*, vol. 27, pp. 421–436; April, (1939).

[5] T. R. Gilliland, S. S. Kirby, and N. Smith, "Characteristics of the Ionosphere at Washington, D. C.," PROC. I.R.E., vol. 27, pp. 226–227; March, (1939).

[6] N. Smith, "Oblique-incidence ionospheric data and the Lorentz polarization term," *Trans. Amer. Geophys. Union of 1939*, p. 375; April, (1939).

[7] D. F. Martyn and G. H. Munro, "Lorentz polarization correction in the ionosphere," *Terr. Mag.*, vol. 44, pp. 1-6; March, (1939).

[8] J. A. Ratcliffe, "Effect of Lorentz polarization term in ionospheric calculations," *Proc. Phys. Soc.* (London), vol. 51, pp. 747–756; September, (1939).

[9] R. C. Majundar, "Reflection of electromagnetic waves in the ionosphere," *Trans. Bose Res. Inst.* (Calcutta), vol. 12, pp. 125–140, (1936–1937).

[10] H. G. Booker and L. V. Berkner, "An ionospheric investigation concerning the Lorentz polarization correction," *Terr. Mag.*, vol. 43, pp. 427–450; December, (1938).

[11] D. R. Goddard, "Observations on sky-wave transmission on frequencies above 40 megacycles," PROC. I.R.E., vol. 27, pp. 12–15; January, (1939); *RCA Rev.*, vol. 3, pp. 309–315; January, (1939).

[12] F. Vilbig, "On the reflection coefficients of the Heaviside layer in the wave band from 200 to 2000 meters for various departure angles," *Teleg.- Fern.- und Funk-Tech.*, vol. 27, pp. 291–294; August, (1938).

[13] S. K. Mitra, J. N. Bhar, and S. P. Ghosh, "The lower ionosphere," *Indian Jour. Phys.*, vol. 12, pp. 455–465; December, (1938).

[14] F. W. G. White and T. W. Straker, "Diurnal variation of absorption of radio waves," *Proc. Phys. Soc.* (London), vol. 51, pp. 865–875; September, (1939).

[15] K. G. Budden, J. A. Ratcliffe, and M. V. Wilkes, "Further investigations of very long waves reflected from the ionosphere," *Proc. Roy. Soc.*, ser. A., vol. 171, pp. 188–214; May, (1939).

[16] M. Waldmeier, "Solar eruptions and their influence on the propagation of electromagnetic waves," *Helvetica Phys. Acta*, vol. 2, pp. 537–538; fasc. 7, (1938).

[17] L. V. Berkner, "Nature of radio fade-out," *Phys. Rev.*, vol. 55, pp. 536–544; March 15, (1939).

[18] R. Jouaust, "Ionosphere and short-wave fade-outs," *Jour. de Phys. et le Radium*, vol. 10, pp. 251–259; June, (1939).

[19] R. Bureau, "Reinforcement of long waves at time of short-wave fade-outs," *Jour. de Phys. et le Radium*, vol. 10, pp. 271–273; June, (1939).

also contributed notably to other fields of science[16,20–25] in particular, terrestrial magnetism, composition of the atmosphere, and physics of the sun.

The field of radio wave propagation lost one of its pioneer investigators through the death of Dr. A. E. Kennelly who died on June 18 at the age of 77. He actively promoted research on radio wave propagation, particularly through the International Scientific Radio Union, up to the time of his death. He was the first to explain long-distance radio propagation in terms of ionized layers in the upper atmosphere. This was recognized in the term Kennelly-Heaviside layer formerly used for the ionosphere.

Medium Frequencies (150 to 1500 Kilocycles)

Some comparisons[26] of the recently developed theoretical formulas and experimental measurements of field intensities showed good agreement. The comparisons included propagation between ground stations and to and between airplanes. The work incidentally demonstrated that ground conductivity can be determined by comparisons between calculated and measured variations of field intensity with elevation of antenna above ground.

Effects of ionospheric storms at broadcast frequencies[27,28] were discovered. Daytime received wave intensities were found to rise during the initial stages of an ionospheric storm and night intensities to drop. The latter effect persisted four or five days after other manifestations of the ionospheric storm had passed. It was thus determined that the effects, reported in last year's Annual Review,[29] (a) low night broadcast-frequency intensities in years of sunspot maximum, and (b) low intensities on paths near the magnetic poles, are largely due to the prevalence of ionospheric storms.

The Joint Coordination Committee on Radio Reception of Edison Electric Institute, National Electrical Manufacturers Association, and Radio Manufacturers Association agreed upon recommendations as to the nature, essential characteristics, and performance of an instrument for the measurement of radio disturbance voltages. Recommended practice was also agreed upon for measuring radio disturbance directly from low- and high-voltage apparatus, for making radio-disturbance measurements along overhead lines, for determining broadcast field intensity levels, and methods of collecting data for the establishment of radio disturbance standards.[30] Relations between peak, effective, and average values of disturbances were investigated.[31]

Many data were collected during the year on the magnitude, nature, and direction of arrival of atmospherics.[26,32–38] This information was also being used for weather prediction and the forecasting of tropical storms.[39–41]

An extensive radio disturbance investigation covering also suppression and control methods was carried on by the Radio Division of the Department of Transport of Canada.[42] The Canadian Government has regulations prohibiting the use of equipment having an unnecessarily large disturbance value. The Department worked in co-operation with the Radio Manufacturers Association (of Canada) and the Society of Automotive Engineers, with the result that many automobile manufacturers made changes in the design of their ignition systems, thus reducing the radiation from their latest types of automobile engines.

Other observers found that the disturbance caused by electric trolley systems could be reduced by means

[20] R. V. Giovanelli and A. J. Higgs, "Radio fade-outs and solar eruptions," *Terr. Mag.*, vol. 44, pp. 181–187; June, (1939).

[21] T. H. Johnson and S. A. Korff, "Radiation from solar flares and radio fade-outs," *Terr. Mag.*, vol. 44, pp. 23–27; March, (1939).

[22] L. d'Azambuja, "Solar eruptions and ionospheric perturbations," *Jour. de Phys. et le Radium*, vol. 10, pp. 274–281; June, (1939).

[23] "Fifth report of the Commission on Solar and Terrestrial Relations," International Council of Scientific Unions. Presented, International Union of Geodesy and Geophysics, Washington, D. C., September, (1939).

[24] J. H. Dellinger, "Ionosphere disturbances, 1937–1938." Presented, I.R.E.-U.R.S.I. meeting, Washington, D. C., April 29, (1939).

[25] R. S. Richardson and R. Minkowski, "The spectra of bright chromospheric eruptions from λ3300 to λ11500. *Astrophys. Jour.*, vol. 89, pp. 347–355; April, (1939).

[26] T. L. Eckersley and G. Millington, "The experimental verification of the diffraction analysis of the relation between height and gain for radio waves of medium lengths," *Proc. Phys. Soc.* (London), vol. 51, pp. 805–809; (1939).

[27] T. R. Gilliland, S. S. Kirby, and N. Smith, "Characteristics of the ionosphere at Washington, D. C." Published each month, Proc. I.R.E.

[28] S. S. Kirby and F. R. Gracely, "Comparions of long-distance broadcast transmissions over different paths," Presented, I.R.E.–U.R.S.I. meeting, Washington, D. C., April 28, (1939).

[29] "Radio progress during 1938," Proc. I.R.E., vol. 27, p. 181; March, (1939).

[30] C. V. Aggers, D. E. Foster, and C. S. Young, "Instruments and methods of measuring radio noise," Proc. I.R.E., vol., 27, p. 408; June, (1939). (Abstract only.)

[31] K. G. Jansky, "An experimental investigation of the characteristics of certain types of noise," Proc. I.R.E., vol. 27, pp. 763–768; December, (1939).

[32] S. P. Chakravarti, P. B. Ghosh, and H. Ghosh, "Atmospherics in radio broadcast reception at Calcutta," Proc. I.R.E., vol. 27, pp. 780–783; December, (1939).

[33] "Australian Radio Research Board, 10th Annual Report: 3. Work on Atmospherics," *Jour. Council Sci. and Indust. Res.*, (Australia), vol. 2, pp. 330–331, 332, November, (1938).

[34] J. P. Schafer and W. M. Goodall, "Peak field strengths of atmospherics due to local thunderstorms at 150 megacycles," Proc. I.R.E., vol. 27, pp. 202–207; March, (1939).

[35] P. Ilardi, "Research on atmospherics in Italy," *Radio e Televisione*, vol. 3, pp. 317–318; March, (1939).

[36] F. E. Lutkin, "The nature of atmospherics, VI," *Proc. Roy. Soc.* (London), vol. 171, pp. 285–313; June, (1939).

[37] S. P. Chakravarti, "On the wave form of atmospherics at Calcutta," *L'Onde Élec.*, vol. 18, pp. 181–186; April, (1939).

[38] T. H. Laby, J. J. McNeill, F. G. Nicholls, and A. F. B. Nickson, "Wave form, energy, and reflection by the ionosphere of atmospherics," *Proc. Roy. Soc.*, vol. 171, p. S 72; July, (1939). (Abstract only.)

[39] S. T. Sashoff and J. Weil, "Static emanating from six tropical storms and its use in locating the position of the disturbance," Proc. I.R.E., vol. 27, pp. 696–700; November, (1939).

[40] "Symposium on weather prediction," *Sci. and Culture*, (Calcutta,) vol. 4, pp. 160–164; September, (1938).

[41] B. Paoloni, "Radio-atmospheric researches," *Bollettino del Centro Volpi di Elettrologia*, year 1, p. 83; December, (1938). (Summary only.)

[42] H. O. Merriman and F. G. Nixon, "Radio interference—Investigation, suppression, and control," Proc. I.R.E., vol. 27, pp. 16–21; January, (1939).

of condensers.[43,44] Other types of disturbance were investigated and methods of reduction found.[45–48] The cause of scattering of results in the measurement of disturbance voltages by the CISPR Technique was studied[49] and a possible remedy suggested. Legislation was enacted in several countries in an effort to reduce the amount of man-made radio noise by control at the source.[42–50] In the large metropolitan areas this is the major source of disturbance.

A co-operative program by a number of investigators[51,52] interested in aircraft radio reception resulted in means of reducing the disturbance called precipitation static. The results of this work were found to be applicable to ground stations.

High Frequencies (1500 to 30,000 Kilocycles)

Radio wave propagation in this range of frequencies is almost entirely by way of the ionosphere. There was substantial progress during the year in the use of ionospheric data to calculate or predict radio transmission conditions. This included methods of calculating[53–55] maximum usable frequencies for any transmission distance from critical frequencies and virtual heights of the ionospheric layers, and working out[56] from such data the choice of optimum frequencies, times at which to shift frequency, etc.

The year saw the inauguration of a regular service of prediction[27,57] of maximum usable frequencies by the National Bureau of Standards; this was given in the monthly ionosphere report in the Proceedings of the Institute of Radio Engineers for the month following the month of publication. The predictions are in the form of graphs for various distances, giving maximum usable frequencies as a function of time of day; they are based on the Bureau's current observations, on its data on the trends[58] of critical frequencies and virtual heights in the 11-year solar cycle, data on seasonal and diurnal variations accumulated over a number of years, and knowledge of solar variations.[59,60] The maximum usable, and also optimum, frequencies in 1939 averaged about 8 per cent lower than in 1938, and about 11 per cent lower than in 1937. By about 1944 they are expected to be about half those of 1937 (last sunspot maximum) and equal to those of 1933 (last sunspot minimum).

Extension of the value of ionospheric data for practical radio purposes depends upon[61] the availability of such data from a number of places on the earth's surface. Ionospheric data taken regularly for all the 24 hours of the day are especially useful. Such data for Washington, D. C., (latitude 39 degrees north) published throughout several past years, continued to appear monthly[27] and quarterly.[62] Such data became available[63,64] for two additional places, Peru (Hunacayo, 12 degrees south), and Australia (Watheroo, 30 degrees south), published quarterly. Valuable but much less complete data were published for three other places.[65,66,67] It was shown[68] that ionospheric characteristics differ somewhat in different places, the differences being small when the places are not over a few hundred miles apart.

It was proved[69] that under some conditions radio waves over long distances deviate considerably from the great-circle plane. In general, on an all-daylight path between England and New York such deviations

[43] S. Lemoine, "Using condensers for eliminating interference from electrical tramways," *Wireless Eng.*, vol. 16, p. 3; January, (1939).

[44] L. A. Fomenko, "The suppression of interference from industrial apparatus by blocking condensers," *Izvestiya Elektroprom. Slab. Toka*, pp. 17–28.

[45] K. Kegel, "General viewpoints of interference suppression," *A. E. G.-Mitteilungen*, pp. 380–383; August, (1939).

[46] "Low-cost cure for radio interference," *Sci. American*, vol. 160, p. 350; June, (1939).

[47] E. T. Glas, "Broadcast interference caused by high-tension installations," *Elek. Tech. Zeit.*, vol. 59, pp. 1305–1306; December, (1938).

[48] "Service instructions for the detection and elimination of interference with radio reception. Instituto Sperimentale delle Communicazioni," *Bolletino del Centro Volpi di Elettrologia*, Year I, p. 73; December, (1938). (Summary only.)

[49] G. Goffin, "A cause of scattering in the measurement of radiophonic interfering voltages," *L'Onde Élec.*, vol. 18, (wrongly printed 19), pp. 57–69; February, (1939).

[50] E. Paolini, "The question of industrial parasites in broadcast reception," *Alta Frequenza*, vol. 8, pp. 377–389; June, (1939).

[51] H. M. Hucke, "Precipitation static interference on aircraft and at ground stations," Proc. I.R.E., vol. 27, pp. 301–316; May, (1939).

[52] Esau, Jansky, Kotowski, and Klumb, "Radio reception in aviation," *Zeit. V.D.I.*, vol. 83, p. 416; April, (1939). (Summaries only.)

[53] N. Smith, "The relation of radio sky-wave transmission to ionosphere measurements," Proc. I.R.E., vol. 27, pp. 332–347; May, (1939).

[54] M. V. Wilkes, "Theoretical ionization curves for the E region." *Proc. Phys. Soc.* (London), vol. 51, pp. 138–146; January, (1939).

[55] H. G. Booker and S. L. Seaton, "Relation between actual and virtual ionospheric height," *Phys. Rev.*, vol. 57, pp. 87–94; January 15, (1940).

[56] N. Smith, S. S. Kirby, and T. R. Gilliland, "Application of graphs of maximum usable frequency to communication problems," *Jour. Res. Nat. Bur. Stand.*, vol. 22, pp. 81–92; January, (1939).

[57] N. Smith and A. S. Taylor, "The prediction of ionosphere characteristics and maximum usable frequencies," Presented, I.R.E.–U.R.S.I. meeting, Washington, D. C., April 29, (1939).

[58] N. Smith, T. R. Gilliland, and S. S. Kirby, "Trends of characteristics of the ionosphere for half a sunspot cycle," *Jour. Res. Nat. Bur. Stand.*, vol. 21, pp. 835–845; December, (1938).

[59] W. M. Goodall, "The solar cycle and the F_2 region of the ionosphere," Proc. I.R.E., vol. 27, pp. 701–704; November, (1939).

[60] C. H. Anderson, "A representation of the sunspot cycle," *Bell Sys. Tech. Jour.*, vol. 18, pp. 292–299; April, (1939).

[61] J. H. Dellinger, "Report of Commission II, Radio Wave Propagation, International Scientific Radio Union," Proc. I.R.E., vol. 27, pp. 645–649; October, (1939).

[62] "Averages of critical frequencies and virtual heights of the ionosphere, observed by the National Bureau of Standards at Washington, D. C." Published quarterly in *Terr. Mag.*

[63] H. W. Wells and H. E. Stanton, "The ionosphere at Huancayo, Peru." Published quarterly in *Terr. Mag.*

[64] W. C. Parkinson and L. S. Prior, "The ionosphere at Watheroo, Western Australia." Published quarterly in *Terr. Mag.*

[65] I. Ranzi, "Ionospheric observations," *La Ricerca Sci.*, vol. 10, pp. 32–38; January-February (1939).

[66] L. Harang, "Annual variation of the critical frequencies of the ionized layers at Tromso during 1938," *Terr. Mag.*, vol. 44, pp. 15–16; March, (1939).

[67] W. M. Goodall, "Midday F_2-region critical frequencies for Deal, New Jersey," *Terr. Mag.*, vol. 44, p. 212; June, (1939).

[68] J. P. Schafer and W. M. Goodall, "Simultaneous ionosphere observations at Washington, D. C. and Deal, N. J.," *Terr. Mag.*, vol. 44, pp. 205–208; June, (1939).

[69] C. B. Feldman, "Deviations of short radio waves from the London–New York great-circle path," Proc. I.R.E., vol. 27, pp. 635–645; October, (1939).

did not occur, and neither ionospheric storms nor sudden ionospheric disturbances affected the mode of propagation. On the other hand, on dark or partially illuminated paths the great circle no longer provides the sole transmission path. The extent to which other paths are involved varies greatly. Propagation during ionospheric storms of moderate intensity usually involves paths deviated to the south of the great circle; at other times propagation may be either to the north or south. The closely related subject of scattered reflections was the subject of considerable investigation.[70–73] Some observations[74] during magnetic storms and annual displays showed that the sporadic E layer has a sharper lower boundary than the normal E layer.

Further data were accumulated on the phenomena characterizing ionospheric storms.[27,28,75] It was established that the effects of this particular type of ionospheric disturbance are less at low than at high latitudes. Effects at broadcast frequencies are reviewed under "Medium Frequencies," above.

A study was made of the vertical angle of arrival of atmospherics.[76] The angle sometimes approaches 90 degrees, becoming lower as the disturbance decreases. An extensive study was made of the spectrum distribution[77] of atmospherics at high frequencies.

Ultra-High Frequencies (Over 30,000 Kilocycles)

Propagation at these frequencies takes place by three means: (a) by ground waves, (b) by tropospheric waves, and (c) at frequencies not very far above 30,000 kilocycles, by ionospheric waves. Progress in regard to (a) ground waves is reviewed in the "General" section above.

Progress in tropospheric wave propagation centered on two principal phenomena. One was the refraction of radio waves around the curved surface of the earth by gradients and discontinuities with height of the dielectric constant of the air. Work[78] in this field confirmed the importance of these phenomena in the application of the ultra-high frequencies to communication services. It was found[79] that these effects may result in either increased or decreased distance ranges of transmission and that it depends particularly on the position (height) of the transmitting and receiving aerials, with respect to the refracting air layers, whether the received field intensity is under or over the normal value. Tropospheric radio transmission was found to have the possibility of applications in meteorology.[80–82]

The second phenomenon of interest in tropospheric wave propagation was the reception of echoes at vertical (or nearly vertical) incidence from heights within the troposphere, i.e., less than about 10 kilometers. It was found that the waves are not reflected from ionized strata but rather are reflected comparatively weakly (reflection coefficients not greater than 10^{-4}) from air-mass discontinuities in which water in its various states plays a dominant rôle.[82–85]

The occurrence of long-distance ionospheric propagation at frequencies up to about 45 megacycles was reported and studied.[11,86,87] This was sometimes not so much by reflection from regular layers of the ionosphere as sometimes by sporadic or scattered reflections.

The problem of interference with television reception was given an increased amount of study. A new noise meter, intended primarily for measuring such interference was developed under the auspices of a Radio Manufacturers Association Subcommittee on Television Interference.[88] In an attempt to promote some constructive action on the serious problem of interference to television and other radio services caused by electromedical equipment, a conference was held in New York in January at which representatives of the American Medical Association, the Federal Communications Commission, various radio societies, and the radio industry were present.[89] Negotiations

[70] L. Harang and W. Stoffregen, "Scattered reflections of radio waves from height of more than 1000 km.," *Nature*, vol. 142, p. 832; November 5, (1938).

[71] T. L. Eckersley, "Scattering of radio waves in the ionosphere," *Nature*, vol. 143, pp. 33–34; January 16, (1939).

[72] E. V. Appleton and R. Naismith, "Scattering of radio waves in polar regions," *Nature*, vol. 143, pp. 243–244; February 11, (1939).

[73] B. Beckmann, W. Menzel, and F. Vilbig, "Scattered reflections in the ionosphere," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 130–135; April, (1939).

[74] L. Harang and W. Stoffregen, "The polarization condition of radio waves by reflection on layers which are formed by magnetic storms and northern lights," *Hochfrequenztech. und Elektroakustik*, vol. 53, pp. 181–187; June, (1939).

[75] L. V. Berkner, H. W. Wells, and S. L. Seaton, "Ionospheric effects associated with magnetic disturbances," *Terr. Mag.*, vol. 44, pp. 283–311; Spetember, (1939).

[76] M. Nakagami and K. Miya, "Incident angle of short waves and high-frequency noise (resembling 'grinders') during Dellinger effect," *Elec. Jour.* (Tokyo), vol. 3, p. 216; September, (1939).

[77] O. Morgenroth, "Atmospheric disturbances," *Funktech. Monatshefte*, no. 3, pp. 70–74; March, (1939).

[78] K. G. MacLean and G. S. Wickizer, "Notes on the random fading of 50-megacycle signals over nonoptical paths," Proc. I.R.E., vol. 27, pp. 501–506; August, (1939).

[79] W. Scholz and L. Egersdorfer, "On the influence of the troposphere on ultra-short-wave propagation," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 77–83; March, (1939).

[80] A. W. Friend, *Bull. Amer. Meteor. Soc.*, vol. 20, pp. 202–205; May, (1939).

[81] A. W. Friend, *Nature*, vol. 144, p. 31: July 1, (1939).

[82] A. W. Friend and R. C. Colwell, "The heights of the reflecting regions in the troposphere," Proc. I.R.E., vol. 27, pp. 626–634; October, (1939).

[83] J. H. Piddington, "The origin of radio-wave reflections in the troposphere," *Proc. Phys. Soc.* (London), vol. 51, pp. 126–137; January, (1939); vol. 51, pp. 547–548; May, (1939).

[84] O. H. Gish and H. G. Booker, "Nonexistence of continuous intense ionization in the troposphere and lower stratosphere," Proc. I.R.E., vol. 27, pp. 117–125; February, (1939).

[85] R. C. Colwell and A. W. Friend, "Tropospheric reflections of radio waves," *U.R.S.I. Proc. of 1938 General Assembly*, vol. 5, pp. 146–149; (1938).

[86] O. Burkard, "Limiting waves and the ionosphere: III," *Hochfrequenz. und Elektroakustik*, vol. 52, pp. 142–146; October, (1938).

[87] D. R. Goddard, "Transatlantic reception of London television signals," Proc. I.R.E., vol. 27, pp. 692–695; November, (1939).

[88] Jerry Minter, "Noise measurements in the television bands," *Electronics*, vol. 12, p. 21; December, (1939). (Abstract only.)

[89] "Summary of informal discussion on interference to radio reception caused by electro-medical equipment, New York, January 9, 1939." Federal Communications Commission, No. 32683. (1939).

were begun between representatives of the automotive industry and the Radio Manufacturers Association, looking toward alleviation of the problem of ignition interference.

Experiments have been carried on in order to determine the effectiveness of frequency modulation in respect to disturbance.[90–92] A considerable advantage in comparison with amplitude modulation was indicated if the peak radio noise voltage is somewhat less than the signal voltage.

Atmospherics at about 150 megacycles were investigated.[34] The technique of observations provided a visual indication of the disturbance which might be expected with television signals. It appears that atmospherics due to thunderstorms will be noticeable for ultra-high-frequency television transmission at times when storms are in progress near the point of reception.

[90] I. R. Weir, "Field tests of frequency and amplitude modulation with ultra-high-frequency waves," *Gen. Elec. Rev.*, vol. 42, pp. 188–191; May, and pp. 270–273; June, (1939). Abstract, Part I, *Electronics*, vol. 12, p. 70; June, (1939).

[91] "The first high-powered radio station without static," *Science*, vol. 89, p. 72; January 27, (1939).

[92] "Frequency modulation demonstrated," *Electronics*, vol. 12, pp. 14–17; March, (1939).

A new line of progress developed in connection with wave guides. The radiation (transmitting and receiving) properties of various types of terminating electromagnetic horns were analyzed[93,94] in detail and practical applications outlined. This work led to some improvements[95,96] in the theory of diffraction of electromagnetic waves.

This report was prepared by the 1939 Technical Committee on Wave Propagation of the Institute of Radio Engineers, the personnel of which follows:

J. H. Dellinger, Chairman

N. I. Adams	*W. A. Fitch*
S. L. Bailey	*G. D. Gillett*
L. V. Berkner	*H. R. Mimno*
C. R. Burrows	*K. A. Norton*
T. L. Eckersley	*H. O. Peterson*

Balth. van der Pol

[93] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," PROC. I.R.E., vol. 27, pp. 51–64; January, (1939).

[94] G. C. Southworth and A. P. King, "Metal horns as directive receivers of ultra-short waves," PROC. I.R.E., vol. 27, pp. 95–102; February, (1939).

[95] J. A. Stratton and L. J. Chu, "Diffraction theory of electromagnetic waves," *Phys. Rev.*, vol. 56, pp. 99–107; July 1, (1939).

[96] S. Schelkunoff, "On diffraction and radiation of electromagnetic waves," *Phys. Rev.*, vol. 56, pp. 308–316; August 15, (1939).

PART IV—TRANSMITTERS AND ANTENNAS*

Transmitters: Marine—Centimeter Waves—Frequency and Phase Modulation—Regulation—Television—Point-to-Point—Instrument Navigation Equipment
Antennas: Television—Steerable Antenna—Horn Radiators

TRANSMITTERS

The year's developments in broadcast transmitters employing amplitude modulation were chiefly along the lines of refinements of earlier fundamental developments. One of such developments is the use of circuits of high power efficiency, whose application has been broadened and improved. For example, several manufacturers now offer air-cooled 5-kilowatt transmitters, the problems of cooling being considerably simplified by improved efficiency. A new 1-kilowatt transmitter appeared in which a high-efficiency circuit is employed in conjunction with grid-bias modulation. At this low power level the advantage lies more in lower tube cost resulting from reduced dissipation than in power saving. Manufacturers of power tubes are extending the use of air-cooling to tubes of higher power. By means of new designs made available late in the year, it became possible to build air-cooled transmitters up to 50 or more kilowatts. New applications of multiphase alternating current for filament lighting were made.

Stabilized feedback continued to be an important feature of transmitter design. Nearly all new transmitters made use of this principle to give high-fidelity performance and to permit less-expensive filtering equipment and alternating-current filament heating.

Modern styling continued to be a feature of broadcast transmitters and associated apparatus.

Refinements in speech-input equipment were evident in circuit design and in equipment arrangement and styling.

A much-needed step was taken in the standardization of the volume unit and its incorporation in a new standard volume indicator.[1]

Marine

In the marine field new radio transmitters were offered by several of the major communication organizations for both the intermediate-frequency and high-frequency bands. These new transmitters are characterized by crystal control. Previously the use of crystal control for ship transmitters was limited and was usually applied to radiotelephone equipment only.

Centimeter Waves

Important progress was made in devices to produce increased power and stability on centimeter waves.

* Decimal classification: R350×R320.

[1] H. A. Chinn, D. K. Gannett, and R. M. Morris, "A new standard volume indicator and reference level," PROC. I.R.E., vol. 28, pp. 1–16; January, (1940).

Common to all of the devices referred to is the use of cathode-ray beams and the use of inductive power generation, the function of electron collecting being assigned to a separate electrode. The cathode-ray beam is varied by some form of control electrode.

There are at least two types of variation used. In one of these[2] the number of electrons in the beam, that is, the electron density, is varied in much the same way as in the conventional triode, by means of a control grid. This variation, produced at the control grid, is maintained (per unit length) substantially constant to the point where power is collected.

In the second type of variation[3–8] called "velocity modulation," the electron velocity, not its density, is varied at the control grid, the requisite variations in density not developing until the electrons have drifted down the beam to the power-collecting point. Different names have been given in different laboratories to the latter type of device, notably "drift tubes" and "Klystrons."

These devices appear to possess certain advantages over conventional types, among which are increased power capability at wavelengths in the decimeter range, reduction of the input-admittance component caused by transit time (at least in the drift-tube type). It is naturally too early to assess their ultimate advatages or disadvantages in radio transmitters, but it can be said that they are already being used for that purpose. A power of 300 watts at 1000 megacycles has been reported with an efficiency of 30 to 40 per cent.[9]

Utilizing an anode-tank-circuit[10] magnetron, an output of 20 watts at 3750 megacycles and an efficiency of 22 per cent have been obtained.

Frequency and Phase Modulation

Considerable interest was shown in frequency and phase modulation[11–13] for services which utilize the ultra-high frequencies. Applications for broadcast licenses to make use of frequency modulation on an experimental basis were being filed with the Federal Communications Commission at a rate of about three a week at the end of the year. Equipment manufacturers offered transmitters for this type of service for operation in the 40,000-kilocycle band and at power outputs ranging from 100 to 50,000 watts. Several receiver manufacturers offered frequency-modulated-wave receivers for sale to the public at prices ranging between $60 and several hundred dollars. Several frequency-modulated-wave broadcast stations were in operation at the end of the year and were transmitting the regular programs carried by stations operating in the 500-to-1600-kilocycle band. One of them utilized 40,000 watts power.

It was demonstrated that frequency modulation occasions a large noise advantage over amplitude modulation provided that the field intensity at the receiving point is somewhat greater than the noise intensity. A large saving in transmitting-tube capacity is also occasioned by frequency modulation because the amplitude of the transmitted wave remains constant during modulation.

The Federal Communications Commission restricted frequency modulation to experimental use in broadcasting and assigned 13 frequencies exclusively for that service. On the basis of preliminary information, it appears that stations may be duplicated on each channel if a geographical separation of roughly 300 miles is maintained.[14] The relaying of programs successively though several frequency-modulated-wave stations was demonstrated.[15]

Regulation

The Federal Communications Commission made sweeping revisions in the "Rules and Standards of Good Engineering Practice" covering many of the radio services. Important changes were made in frequency-allocation requirements for minimum and maximum powers, permissible carrier-frequency tolerances, safety requirements, procedure, antenna requirements, etc. Most of the changes became effective during the year, but some will become effective in 1940 and 1941.

Television

The year 1939 marked the inauguration of the first regularly scheduled and permanent television service to the public in the Americas. Approximately 12 program hours per week were provided in the areas served. These programs consisted of motion pictures, dramatic, comedy, and variety productions, news, and sporting events direct from the scene of action. Trans-

[2] A. V. Haeff, "A new ultra-high-frequency amplifier of unique design," *Electronics*, vol. 12, pp. 30–32; February, (1939).
[3] W. C. Hahn and G. F. Metcalf, "Velocity-modulated tubes," PROC. I.R.E., vol. 27, pp. 106–116; February, (1939).
[4] W. W. Hansen and R. D. Richtmyer, "On resonators suitable for Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 189–199; March, (1939).
[5] W. C. Hahn, "Small signal theory of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, p. 258–270; June, (1939).
[6] Simon Ramo, "Space charge and field waves in an electron beam," *Phys. Rev.*, vol. 56, p. 276–283; August 1, (1939).
[7] W. C. Hahn, "Wave-energy and trans-conductance of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 497–502; November 19, (1939).
[8] Simon Ramo, "The electronic-wave theory of velocity-modulation tubes," PROC. I.R.E., vol. 27, pp. 757–763; December, (1939).
[9] "Cathode-ray amplifier tubes," *Electronics*, vol. 12, p. 9; April, (1939).
[10] E. G. Linder, "The anode-tank-circuit magnetron," PROC. I.R.E., vol. 27, pp. 732–738; November, (1939).
[11] M. G. Crosby, "Communication by phase modulation," PROC. I.R.E., vol. 27, pp. 126–136; February, (1939).
[12] J. R. Carson, "Frequency modulation: Theory of the feedback receiving circuit," *Bell Sys. Tech. Jour.*, vol. 18, pp. 395–403; July, (1939).
[13] J. G. Chaffee, "The application of negative feedback to frequency-modulation systems," PROC. I.R.E., vol. 27, pp. 317–331; May, (1939); *Bell. Sys. Tech. Jour.*, vol. 18, pp. 404–437; July, (1939).
[14] I. R. Weir, "Field tests of frequency and amplitude modulation with ultra-high-frequency waves," *Gen. Elec. Rev.*, vol. 42, pp. 188–191 and 270–273; May and June, (1939). Abstract Part I, *Electronics*, pp. 12, 70; June, (1939).
[15] "F-M broadcasting on three relays proves successful," *Broadcasting*, vol. 17, p. 26; December 15, (1939).

mitters became available as standard equipment, and television receivers were sold to the public for the first time. Although the Federal Communications Commission has not authorized commercial operation, one class of station is permitted to accept payment sufficient to cover the costs of program production.

At one station a radio link between the studio and and transmitter site is used to relay the programs. Television programs have been successfully received from a New York City station and relayed over a station near Schenectady (129 miles).

Point-to-Point

Developments in commercial telephone-communication channels during the year included modification for twin-channel operation of the single-channel, single-sideband short-wave circuit between San Francisco and Honolulu and the addition of a second such circuit to the existing one between New York and London. Twin-channel operation denotes the operation of two channels, one in each sideband of the same carrier frequency. The single-channel single-sideband long-wave transmitter at Rocky Point, Long Island, has also been modified for twin-channel operation.[16]

The requirement of constant supervision of a transatlantic radiotelephone channel by a technical operator was reduced to occasional supervision only by the use of a semiautomatic control terminal which incorporates, for control of transmitting volume,[17] a vogad (voice-operated gain-adjusting device) and for control of receiving volume a tola (tone-operated loss adjuster).

The development of measuring equipment for commercial use at ultra-high frequencies provided means for overcoming the widespread uncertainty as to ultra-high-frequency transmission conditions.

Instrument Navigation Equipment

An instrument landing system utilizing[18] 40-centimeter (750-megacycle) waves was demonstrated to Civil Aeronautics Authority officials at East Boston airport. Two metal-horn radiators were fed by separate transmitters, one modulated at 90 cycles and the other at 150 cycles and both operating on a frequency of approximately 750 megacycles. The horns, each of which produces a flat horizontal beam, are inclined, respectively, 5 and 10 degrees above the earth's surface. The beams overlap providing a gliding signal. This vertical guidance system was supplemented by a horizontal guidance system of conventional design. The 700-megacycle transmitters were designed for the Klystron tube which, in other tests utilizing less than 100 watts power, had shown the system described to be effective at a distance of 25 miles. A somewhat different system for instrument landing[19] has been accepted by the Civil Aeronautics Authority and will be placed in service in 1940 and 1941 at many of the country's major airports. This system was demonstrated at the Indianapolis Airport. It consists of a glide-path beam and two marker beams. The outer marker transmitter produces a modulated vertically directed local signal about two miles from the airport on the line of approach and indicates to the pilot that he should start his glide. The second marker transmitter, modulated differently from the first indicates that the airplane has reached the area where contact may be made with the ground. A glide-path transmitter gives vertical guidance throughout the approach. The marker units operate on 75 megacycles with 5 watts, the outer unit modulated at 400 cycles keyed twice per second and the inner unit at 1300 cycles keyed at six pulses per second. The localizer transmitter operates on 109.9 megacycles with 300 watts.

Radio altimeter equipment[20] was offered for commercial use. It gives continuous and instantaneous readings of the distance between plane and terrain throughout an altitude range of from 50 to 5000 feet. The indication of altitude is independent of changes in air pressure, temperature inversions, humidity, cloud layers, and other variable factors of weather. It is not affected by static and requires no adjustment by the pilot. Absolute altitude above the terrain is indicated by sending a frequency-modulated wave to the ground and timing the interval required for it to reach the ground and return to the plane after it has been reflected from the ground. The direct and reflected signals are applied to a detector circuit in a radio receiver and their instantaneous difference in frequency is directly proportional to the height of the airplane above ground. The frequency difference is applied to a cycle-counting circuit including a meter with the scale calibrated in feet of altitude, and this meter is located on the airplane instrument panel in full view of the pilot.

Antennas

The year 1939 saw further increase in the use of directive antenna arrays for broadcast service. The broadcast frequencies are now so well occupied throughout the country that it is seldom possible to secure Federal Communications Commission approval for a new station without using a directive array. Such an array serves one or both of two purposes, namely, to reduce radiation in certain directions to protect other stations from interference and to concentrate radiation toward preferred service areas.

[16] A. A. Oswald, "A short-wave single-side-band radiotelephone system," Proc. I.R.E., vol. 26, pp. 1431–1454; December, (1938).

[17] S. B. Wright, S. Doba, and A. C. Dickieson, "A vogad for radiotelephone circuits," Proc. I.R.E., vol. 27, pp. 254–257; April, (1939).

[18] "40-cm. waves for aviation," *Electronics*, vol. 12, pp. 12–15; November, (1939).

[19] "Instrument landing systems," *Communications*, vol. 19, pp. 9, 25, 26, 29; November, (1939).

[20] Lloyd Espenschied and R. C. Newhouse, "A terrain clearance indicator," *Bell Sys. Tech. Jour.*, vol. 18, pp. 222–234; January, (1939).

In line with the more-intense interest being shown in antenna performance, a few investigators have undertaken to verify the performance of antennas above the horizontal plane by airplane surveys. A certain amount of work was also done on vertical patterns by means of scale models at ultra-high frequencies.

At ultra-high frequencies experimentation continued with a variety of directional-antenna forms. Such experimentation naturally yields results more readily than at broadcast frequencies because of the more-practical physical dimensions involved.

It was reported during the year[21] that progress with the multiple-unit steerable receiving antenna (musa), previously described[22] reached the stage of commercial application on radiotelephone circuits between New York and London.

Television

The requirement of nondirectional coverage in a horizontal plane for broadcast service resulted in the development of the turnstile antenna described in previous reports. The added requirement of wide frequency band width for television service was met during the current year. This development, although rapid, was made in gradual steps starting from the conventional dipole, going to a similar radiator but with large-diameter conductors, then to the "folded" dipole and combinations of them, and finally coming to the "double-cone" radiator as the last step in the simple-antenna series.

A television antenna successfully meeting the broadband requirement of the new standards was developed and installed atop the Empire State Building in New York City.[23,24] This structure is basically of the turnstile form, consisting of two horizontal half-wave resonators set at right angles and excited in quadrature. The noteworthy features are the careful proportioning of parts to the end that the coaxial transmission lines feeding the antenna are properly terminated at their characteristic impedance, without the use of additional circuits for the purpose located at the antenna and the extremely wide band of frequencies transmitted with negligible reflection. The four quarter-wave radiators are ellipsoidal in shape and with their collars are proportioned so that the square root of the inductance-capacitance quotient in effect has been made equal to the radiation resistance, and departs little from this condition over a band six times that assigned for a single television channel.

The sound antenna consists of 4 folded dipoles arranged in the form of bent segments in a horizontal plane around a central support and above the plane of the vision antenna. The canceling effect of the opposite segments as connected to the common transmission line feeding the segments in parallel results in the approximate equivalent of a loop antenna with almost complete freedom from coupling to the diametrically located radiators of the vision antenna. This feature is interesting because it permits the two antennas to operate without mutual interference in such close proximity.

Steerable Antenna

There has been an application in America and one in Europe of steerable directive transmitting antennas for international broadcasting. By the use of remotely controlled phasing units in the feed circuits to the several bays comprising a directive antenna, the direction of maximum transmission may be shifted to preselected areas. This use of controllable horizontal directivity makes possible flexibility and economies in the number of high-gain antennas required to provide optimum service.

Horn Radiators

It was shown that metal horns have many[25–27] advantages for transmission and reception of electromagnetic waves at wavelengths below 100 centimeters. Some of the advantages consist of unusual freedom from secondary lobes and stray radiation, simple construction, transmission of a very broad band width, ease and stability of operation, and high power gain. The power gain is roughly proportional to the area of aperture. Power gains of over 100 are obtained without difficulty and there is no reason to believe that this is an upper limit. Through the use of combinations of horns and variations in their configurations, a variety of specialized requirements may be met. An airplane instrument blind-landing system is one application.

This report was prepared by the 1939 Technical Committee on Transmitters and Antennas of the Institute of Radio Engineers, the personnel of which follows:

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[21] F. A. Polkinghorn, "A single-sideband MUSA receiving system for commercial operation on transatlantic radiotelephone circuits," PROC. I.R.E., vol. 27, p. 614; September, (1939). (Abstract only.)

[22] H. T. Friis and C. B. Feldman, "A multiple unit steerable antenna for short-wave reception," PROC. I.R.E., vol. 25, pp. 841–917; July, (1937).

[23] N. E. Lindenblad, "Television transmitting antenna for Empire State Building," *RCA Rev.*, vol. 3, pp. 387–408; April, (1939).

[24] P. S. Carter, "Simple television antennas," *RCA Rev.*, vol. 4, pp. 168–185; October, (1939).

[25] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," PROC. I.R.E., vol. 27, pp. 51–64; January, (1939).

[26] G. C. Southworth and A. P. King, "Metal horns as directive receivers of ultra-short waves," PROC. I.R.E. vol. 27, pp. 95–102; February, (1939).

[27] W. L. Barrow and F. D. Lewis, "The sectoral electromagnetic horn," PROC. I.R.E., vol. 27, pp. 41–50; January, (1939).

PART V—RADIO RECEIVERS*

Broadcast Receivers—Communication Receivers—Navigational-Aid Receivers—Measuring Apparatus and Technique—Statistics

Broadcast Receivers

The general use of the loop antenna in broadcast receivers was occasioned primarily by the desire to eliminate the inconvenience of installing a conventional antenna and, secondarily, by the desire to minimize noise interference. Those receivers designed to reduce susceptibility to external noise incorporated an electrostatic shield for the loop. The use of such shielding enhanced the directional properties of the loop by reduction of electrostatic pickup, so that such receivers when of the console type usually incorporated a rotatable loop. Loop rotation controllable from the front of the receiver was used in but few models, however.

The use of the loop was extended to the short-wave band in several models; in others the broadcast-band loop or the shielding thereof was used as an electrostatic-pickup-type antenna on short-wave bands.

Untuned radio-frequency stages were used to improve sensitivity in several models. The untuned stage was usually designed to have substantial gain (6 to 20 decibels) up to approximately 18 megacycles when used with a high-transconductance tube.[1] In other models an untuned intermediate-frequency stage was used.

Untuned antenna circuits using inverse feedback for reduction of cross modulation were employed in some commercially available models.

Receivers appeared on the market incorporating continuous permeability tuning over the entire standard broadcast band. Permeability tuning of the loop circuit by variation of an inductance in series with the loop was used in some models.

Portable receivers using a loop antenna and powered by dry batteries became very popular and because of the use of 1.4-volt filament-type tubes gave good performance with a useful battery life of about 250 hours.

Receivers were introduced which operated from alternating-current, direct-current, or battery power supply, some of which were equipped with relays for automatically transferring from the self-contained batteries to the (rectifier) power-supply unit when plugged into an alternating-current or direct-current outlet.[2]

Many more receiver models than in the past few years incorporated the broadcast band only, thus recognizing that for entertainment purposes the short-wave bands are little used. However, war in Europe increased interest in and the use of short-wave bands on receivers so that while there were fewer models with short-wave bands, actual usage of short-wave bands in receivers increased.[3,4]

Receivers designed for reception of frequency-modulated waves were the subject of much attention during the past year, and several models were placed on the market. These included table models, designed for reception of frequency-modulated waves in the 40-to-45-megacycle band only, as well as console models for reception of this band in addition to amplitude-modulated-wave reception in the broadcast and short-wave bands. Frequency-modulated-wave receivers were generally of the superheterodyne type, using an intermediate frequency between 1.5 and 4.0 megacycles with a band width of approximately 200 kilocycles and embodied amplitude-limiting and frequency-discrimination circuits.[5–7]

A system of reception of frequency-modulated waves was described in which a portion of the output voltage is fed back to the local oscillator to produce frequency modulation thereof in inverse phase. As a consequence the necessary pass band of the amplifier circuits of the receiver is reduced, distortion arising therein minimized, and effects on noise disturbances similar to those obtained by amplitude limiting secured.[8]

The signal-to-noise characteristics of phase-modulated-wave reception were investigated, and it was shown that the signal-to-noise ratio at the ouput of the receiver is equal to the product of the phase deviation in radians and the carrier-noise ratio. A new type of receiver using an off-neutralized crystal filter was described and other methods of phase-modulated-wave reception discussed.[9]

Many different designs of table-model radio-phonograph combinations appeared on the market.[10] The use of automatic record-changers increased greatly. Interest in home recording was revived and new low-priced plastic record blanks became available for this use.[11]

In many receiver models provision was made for

* Decimal classification: R360.

[1] D. G. Fink, "Circuits you'll see tomorrow," *Rad. and Telev. Ret.*, vol. 24, p. 42; June, (1939).

[2] "Triplex-portable principles," *Rad. and Telev. Ret.*, vol. 24, p. 62; October, (1939).

[3] "War revitalizes short waves," *Rad. and Telev. Ret.*, vol. 24, p. 20; October, (1939).

[4] "War stimulates short wave interest," *Rad. and Telev. Today*, vol. 24, p. 14; October, (1939).

[5] J. R. Day, "Receiver for frequency modulation," *Electronics*, vol. 12, pp. 32–35; June, (1939).

[6] G. W. Fyler and J. A. Worcester, Jr., "A noise-free radio receiver," *Gen. Elec. Rev.*, vol. 42, pp. 307–310; July, (1939).

[7] G. W. Fyler and J. A. Worcester, Jr., "A new Armstrong frequency-modulated-wave receiver," *Proc. Radio Club Amer.*, vol. 16, pp. 16–18; July, (1939).

[8] J. G. Chaffee, "The application of negative feedback to frequency-modulation systems," Proc. I.R.E., vol. 27, pp. 317–331; May, (1939); *Bell Sys. Tech. Jour.*, vol. 18, pp. 404–437; July, (1939).

[9] M. G. Crosby, "Communication by phase modulation," Proc. I.R.E., vol. 27, pp. 126–136; February, (1939).

[10] "Compact combinations are hot," *Rad. and Tel. Ret.*, vol. 24, pp. 16–17; October, (1939).

[11] "Recordio," *Rad. and Telev. Ret.*, vol. 24, p. 55; October, (1939).

using the audio-frequency system for television sound. Other models had complete ultra-high-frequency systems, a doubly resonant intermediate-frequency system being employed in some receivers, resonant to 455 kilocycles for broadcast-band reception and to approximately 3000 kilocycles for ultra-high-frequency reception.[1]

A radio receiver appeared on the market which incorporated, in addition to its conventional functions, an oscillator capable of transmitting the received program over power wires to other receivers in the same house equipped with appropriate coupling means to the power lines.[12]

In Great Britain progress in radio receivers was in improvement of tone-control systems and oscillator stability, the use of output stages with higher output, and simplification and improvement of push-button tuning.[13]

A method employing a nonreversible motor for tuning and wave-band switching in connection with magnetically operated clutches was described.[14]

Circuit Trends

A method of compensating for variation in input capacitance of vacuum tubes with bias by simultaneous application of proportional bias to two electrodes was described.[15]

It was pointed out that the effective internal impedance of an amplifier may be either increased or decreased by proper choice of the type of feedback and that impedance-reducing feedback circuits, when applied to audio-frequency power amplifiers, flatten the response and improve loud-speaker damping. Circuits for impedance-increasing feedback have been described also as a means for improving the selectivity of intermediate-frequency amplifiers.[16]

A treatment of the problems of distributed couplings in ultra-high-frequency circuits was developed by applying low-frequency circuit-analysis methods.[17]

The function of the receiver in the broadcast system was described and possible directions of future progress in receivers pointed out.[18]

An investigation of the composite characteristics of broadcast receivers in use today was made with particular reference to characteristics influenced by the existing broadcast transmission system.[19]

The subject of noise interference with radio reception received much attention in this country and abroad. Methods of measuring radio noise were described using noise meters developed especially for that purpose. Instruments have been designed to measure noise in the frequency spectrum from 150 kilocycles to 20 megacycles and also for the ultra-high-frequency range from 20 megacycles to 125 megacycles. Means of controlling radio interference arising in both low- and high-voltage equipment were also described.[20–23]

Measurement and suppression of radio noise in Canada is carried out by the Radio Division of the Department of Transport. In that country thirty-three automobiles carrying special interference-measuring equipment are in use for noise originating in streetcars, electromedical apparatus, and domestic and commercial electrical equipment. The methods of applying appropriate noise suppression to these various types of apparatus have also been described.[24] Methods of reducing interference to broadcast reception caused by electric railways have been studied abroad with particular regard to the efficacy of capacitors in preventing such interference.[25]

Component Parts

Polystyrene insulating material has been used widely for coil forms, capacitor supporting pieces, and as a dielectric, particularly at ultra-high frequencies where its unusually good power factor has proved to be of decided advantage.[26]

Flexible transmission lines having exceptionally low losses up to 300 megacycles were developed through the use of spun-glass or polystyrene insulation.

Spun-glass insulated wire became available, combining low-loss characteristics with noninflammable properties.

The use of fabricated-plate[27] and deep-etched electrolytic condensers increased markedly because of their small size and improved seal.

[12] "Multiplex-superhet," *Rad. and Telev. Ret.*, vol. 24, p. 52; July, (1939).

[13] "The wireless exhibition, 1939: A technical survey," *Wireless Eng.*, vol. 16, pp. 500–510; October, (1939).

[14] "Simplifying press-button tuning," *Wireless World*, vol. 45, pp. 87–88; July 27, (1939).

[15] J. F. Farrington, "Compensation of vacuum-tube input capacitance by bias-potential control," *R.M.A. Eng.*, vol. 4, pp. 13–15; November, (1939).

[16] H. F. Mayer, "Control of the effective internal impedance of amplifiers by means of feedback," PROC. I.R.E., vol. 27, pp. 213–217; March, (1939).

[17] Ronold King, "The application of low-frequency circuit analysis to the problem of distributed coupling in ultra-high-frequency circuits," PROC. I.R.E., vol. 27, pp. 715–724; November (1939).

[18] A. F. Van Dyck, "The radio receiver as part of the broadcast system," *Communications*, vol. 19, pp. 8–11; March, (1939); and pp. 7–9, 44 46; April, (1939).

[19] D. E. Foster, "Receiver characteristics: Special significance to broadcasters," *Communications*, vol. 19, pp. 9–13, 36–37; May, (1939).

[20] C. V. Aggers, D. E. Foster, and C. S. Young, "Instruments and methods of measuring radio noise," PROC. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

[21] C. V. Aggers, "Methods of controlling radio interference," PROC. I.R.E., vol. 27, p. 408; June, (1939). (Summary only.)

[22] Jerry Minter, "A noise meter for television frequencies," *Electronics*, vol. 12, p. 21; December, (1939). (Abstract only.)

[23] C. M. Burrill, "Progress in development of instruments for measuring radio noise," *Electronics*, vol. 12, p. 24; December, (1939). (Abstract only.)

[24] H. L. Merriman and F. G. Nixon, "Radio interference—Investigation, suppression, and control," PROC. I.R.E., vol. 27, pp. 16–21; January, (1939).

[25] S. Lemoine, "Using condensers for eliminating interference from electrical tramways," *Wireless Eng.*, vol. 16, pp. 3–5; January, (1939).

[26] "Polystyrene: Its characteristics and application in short-wave equipment," *Wireless World*, vol. 16, p. 297; September, (1939).

[27] "Electrolytic condensers with fabricated plates," PROC. I.R.E., vol. 27, pp. viii, x; January, (1939).

Communication Receivers

In the field of communication receivers the use of crystal-controlled oscillator circuits in superheterodyne receivers was extended.

Receivers appeared on the market designed for dual-channel diversity reception in which two antenna and radio-frequency channels, a single-oscillator circuit, and dual intermediate-frequency channels were incorporated in a single cabinet.

A receiver was described in which regeneration was employed in both radio-frequency and intermediate-frequency circuits to improve sensitivity and selectivity.[28]

Portable communication receivers equipped with compact dry batteries and using 1.4-volt tubes to give improved performance and battery life, became commercially available.

The use of crystal-filter preselector circuits in aeronautical ground-station receivers to permit reception adjacent to a transmitter was described.[29]

Navigational-Aid Receivers

The special problems connected with radio reception for aircraft navigation and landing were the subject of much study during the past year.[30] An instrument landing system was described involving the use of horn radiators at ultra-high frequencies to produce a triangulation effect which delineates both bearing and glide paths on a visual indicator on the airplane.[31–33]

Bearing errors due to abnormal wave polarization in closed-loop direction finders operating at 450 kilocycles were studied and an empirical formula developed permitting calculation of bearing error for any given polarization or angle of arrival of the wave front.[34]

The effects of mountains on radio direction finding in aircraft were studied also.[35]

A study of precipitation-static generation by airplanes in flight has indicated that the interference with radio reception which occurs under certain meteorological conditions is due to corona discharge. A corona-discharge system located at a point on the airplane remote from the receiving antenna has been developed and has led to marked improvement in reception under precipitation-static conditions.[36]

A method of testing radio compasses in laboratory shielded rooms was described utilizing the radio-frequency field from a transmission line.[37]

A theory of the behavior of shielded receiving loop antennas was developed and the effects of shielding on the performance of the loop analyzed.[38]

A study of some of the peculiar properties of automatic direction-finding equipment caused by continuous loop rotation was made.[39]

It was pointed out that the use of nonlinear amplifiers results in improved precision of direction-finding observations.[40]

Radio equipment installed on coastal-harbor craft, such as yachts and fishing vessels, increased during the year more than two to one, bringing the total installations in this class of service to approximately 2000. The volume of telephone traffic in this type of service likewise increased markedly during the year. Equipment for this service which uses a superheterodyne receiver having 10 crystal-controlled reception frequencies and voice-operated switching means[41] was described.

Measuring Apparatus and Technique

An impedance-measuring instrument became available using the parallel-T circuit for measuring both resistive and reactive parallel components at any frequency in the range from 500 kilocycles to 30 megacycles.[42]

An amplifier suitable for amplifying small direct-current and low-frequency transient potentials was described which uses a balanced modulator with an applied carrier. The voltage to be amplified serves to unbalance the modulator and, after amplification as a carrier variation, is rectified in the output circuit.[43]

A simple oscillator circuit was described in which, by means of impedance transformation, the tube impedances are made small relative to those of the tuned circuit. As a result frequency variations inherent in the tube are much reduced. The method described is

[28] McMurdo Silver, "A new communication receiver kit," *Radio*, no. 239, pp. 46–49, 84–85; May, (1939).

[29] P. C. Sandretto, "Some principles in aeronautical ground-radio-station design," Proc. I.R.E., vol. 27, pp. 5–11; January, (1939).

[30] H. H. Willis, "Recent developments in aerial navigation," Proc. I.R.E., vol. 27, p. 416; June, (1939). (Summary only.)

[31] E. L. Bowles, "Aircraft instrument landing research at the Massachusetts Institute of Technology," Proc. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

[32] W. L. Barrow and F. D. Lewis, "The sectoral electromagnetic horn," Proc. I.R.E., vol. 27, pp. 41–50; January, (1939).

[33] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E., vol. 27, pp. 51–64; January, (1939).

[34] R. I. Cole, "Errors in closed-loop direction finders caused by abnormal polarization," Proc. I.R.E., vol. 27, p. 609; September, (1939). (Summary only.)

[35] Andrè Busignies, "Study of the effects of mountains in radiogoniometry and of the combined use of radio beacons and radio compasses for radio navigation," Proc. I.R.E., vol 27, p. 410; June, (1939). (Summary only.)

[36] H. M. Hucke, "Precipitation-static interference on aircraft and at ground stations," Proc. I.R.E., vol. 27, pp. 301–316; May, (1936).

[37] R. J. Framme, "Aircraft radio compasses, principles and testing," Proc. I.R.E., vol. 27, p. 610; September, (1939). (Summary only.)

[38] R. E. Burgess, "The screened loop aerial," *Wireless Eng.*, vol. 16, pp. 492–499; October, (1939).

[39] Jean Marique, "Automatic radiogoniometers: Methods of measuring the time constants of oscillating circuits," *Wireless Eng.*, vol. 16, pp. 121–124; March, (1939).

[40] W. Ross and R. E. Burgess, "Direction finding: Improvement in the quality of observations by the use of non-linear amplifiers," *Wireless Eng.*, vol. 16, pp. 399–401; August, (1939).

[41] J. D. McDonald, "Medium-power marine radiotelephone equipment," Proc. I.R.E., vol. 27, p. 614; September, (1939). (Summary only.)

[42] D. B. Sinclair, "A parallel-T circuit for measuring impedance at radio frequencies," Proc. I.R.E., vol. 27, p. 615; September, (1939). (Summary only.)

[43] L. J. Black and H. J. Scott, "A direct-current and audio-frequency amplifier," Proc. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

applicable from audio frequencies to ultra-high frequencies.[44]

Signal-generating and measuring equipment was made commercially available which extended the upper frequency limit of such apparatus to 325 megacycles.

Service equipment, more convenient and reliable to use, was made available employing radio frequencies for receiver testing and checking of components.[45] Several such instruments enable checking of radio-frequency and audio-frequency circuits by tracing the passage of the signal either through or around each stage thereby greatly assisting in identifying the nature and location of the fault.

Rapid means of determining the response characteristics of audio-frequency amplifiers were described, one method involving the associated steady-state phase shift and another method involving the application of square waves.[46,47]

Cathode-ray-oscilloscope circuit-control equipment primarily for observation and analysis of transient phenomena in electrical systems was described.[48]

The problems connected with the use of field-intensity-measuring equipment in automobiles were studied.[49]

Statistics on Broadcast Receivers for the United States[50]

Average List Prices of 1939 Models

All models	$ 56.00
Table models	22.00
Consoles	104.00
Phonograph-radio combinations	115.00
Portables	26.00
Total number models	921

Types of Models

Table models	50%
Console models	17%
Phonograph combinations	22%
Combinations using automatic record changers	5%
Portable models	11%
Models covering broadcast band only	47%
Models with loop antenna	31%
Portables working on power lines as well as batteries	3%
Models equipped with automatic tuning	30%
Models with radio-frequency stages	10%
Average number of tubes	6.6

Manufactured Quantities

Receivers, approximately	9,000,000
Vacuum tubes, approximately	100,000,000
New receiving tube types announced	140

The number of receiver models is approximately the same as for last year, in fact has shown little change for several years past.

The average list prices show a decrease of about 20 per cent as compared with those for 1938.

The proportion of table models differs little from the previous year but the proportion of console models dropped sharply, with a corresponding rise in phonograph-combination and portable models.

The quantity of receivers and the quantity of tubes manufactured is approximately 50 per cent greater than for 1938 and constitutes an all-time high for radio production in the United States.

The number of new receiving-tube types introduced likewise sets a new record, being more than twice as great as the number introduced last year. The large number of new tube types was occasioned by two factors: the appearance of new and smaller physical forms and the use of higher filament voltages for series operation. Toward the end of the year a movement developed among some of the tube manufacturers towards a preferred list of tube types, intended to supply requirements of all essential functions but without unnecessary duplication.

A number of developments reported during 1938 had their first formal publication in 1939.[51–55]

This report was prepared by the 1939 Technical Committee on Radio Receivers of the Institute of Radio Engineers, the personnel of which follows:

D. E. Foster, Chairman

E. H. Armstrong	*C. J. Franks*
C. R. Barhydt	*V. M. Graham*
L. B. Blaylock	*David Grimes*
R. I. Cole	*D. E. Harnett*
W. F. Cotter	*R. S. Holmes*
L. F. Curtis	*D. D. Israel*
Harry Diamond	*H. O. Peterson*
E. T. Dickey	*A. E. Thiessen*
H. B. Fischer	*H. J. Tyzzer*

Lincoln Walsh

[44] G. F. Lampkin, "An improvement in constant-frequency oscillators," Proc. I.R.E., vol. 27, pp. 199–201; March, (1939).

[45] "Test oscillators," Proc. I.R.E., vol. 27, p. ii; September, (1939).

[46] Karl Spangenberg and Winslow Palmer, "A phase-shifting device for the rapid determination of audio-frequency amplifier characteristics," Proc. I.R.E., vol. 27, pp. 555–558; September, (1939).

[47] L. B. Arguimbau, "Audio-frequency testing with square waves," *Electronics*, vol. 12, pp. 23–24; December, (1939). (Abstract only.)

[48] G. J. Siezen, "Impulse testing," *Wireless Eng.*, vol. 61, pp. 391–399; August, (1939).

[49] J. H. DeWitt, Jr., and A. C. Omberg, "The relation of the carrying car to the accuracy of portable field-intensity-measuring equipment," Proc. I.R.E., vol. 27, pp. 1–4; January, (1939).

[50] W. MacDonald, "About merchandise," *Radio and Telev. Ret.*, vol. 24, pp. 16–17, 24, 25, 28, 30–31, 35, 36, 39, 60; July, (1939).

[51] V. D. Landon and J. D. Reid, "A new antenna system for noise reduction," Proc. I.R.E., vol. 27, pp. 188–191, March, (1939). (See reference 17 in 1938 report.)

[52] H. B. Fischer, "Remotely controlled receiver for radiotelephone systems," Proc. I.R.E., vol. 27, pp. 264–269; April, (1939). (See reference 32 in 1938 report.)

[53] R. S. Bair, "Ship equipment for harbor and coastal radiotelephone service," Proc. I.R.E., vol. 27, pp. 258–263; April, (1939). (See reference 33 in 1938 report.)

[54] F. E. Terman, R. R. Buss, W. R. Hewlett, and F. C. Cahill, "Some applications of negative feedback with particular reference to laboratory equipment," Proc. I.R.E., vol. 27, pp. 649–655; October, (1939). (See reference 49 in 1938 report.)

[55] G. R. Mezger, "Oscillograph design considerations," Proc. I.R.E., vol. 27, pp. 192–198; March, (1939).

PART VI—TELEVISION*

System Aspects—Transmitters—Receivers

A noticeable increase in television activities was evidenced during the year, both here and abroad. In the United States these activities were particularly stimulated by the inauguration of public program service in the New York area and the introduction of receivers on the market. In England, increased activities were apparent from reports of a large increase in receiver sales; a public service was inaugurated in France, and in Germany public service was anticipated in the early fall. However, most of the European television broadcast activities were apparently stopped later in the year by the outbreak of hostilities.

System Aspects

Theoretical Studies

Fundamental studies of requirements for television transmission were carried out along several different lines. One important aspect of these studies relates to the contrast required to obtain the best reproduction, this contrast being an over-all quantity for the system as a whole and affected by the individual capabilities of the transmitter, receiver, and transmitting medium.[1,2]

Other studies, experimental as well as theoretical, have been concerned with the most efficient use of a given frequency band and deal with such matters as frame-repetition rate, spot size and shape (vertical versus horizontal definition), and with the comparative merits of monochrome, three-color, and stereoscopic television.[3–6]

Investigations continued on circuits and circuit analysis related to television, indicating a better understanding of factors affecting performance.[7–12]

A mathematical analysis was made on the relative merits of vestigial-sideband versus double-sideband transmission,[13] and a theoretical study presented on a method for evaluating phase and amplitude distortion in wide-band systems.[14]

In a German discussion of single-sideband transmission the conclusion was reached that the special vestigial-sideband-shaping filter should be placed in the transmitter.[15]

Standards

In the United States the Radio Manufacturers Association adopted two additional standards, relating to vestigial-sideband transmission and direction of scanning and a recommended practice on polarization of the radiated wave. The most significant of these standards is the one relating to vestigial-sideband transmission, which prescribes unattenuated transmission of the carrier and upper video-frequency sideband, specifies the attenuation characteristic for the lower video-frequency sideband, and contemplates a receiver characteristic that cuts off in linear fashion through the carrier frequency.

These new standards, together with the 14 standards previously adopted, constitute a complete set of primary system standards. They were formally submitted to the Federal Communications Commission by the Radio Manufacturers Association with the recommendation that they be adopted as official standards for television broadcasting in the United States.[16,17] By the end of the year the majority of the television stations in the United States were operating under recommended standards of the Radio Manufacturers Association.

The Television Committee of the Federal Communications Commission, in a report[18] released on November 15, acknowledged recent progress in television broadcasting and recommended liberalization of existing regulations as an aid to further progress in the new art but warned against premature standardization and unlimited commercialization at this time. Transmitters in the New York, Chicago, and Los Angeles areas began regular scheduled service using Radio Manufacturers Association standards.

* Decimal classification: R.583.

[1] I. G. Maloff, "Gamma and range in television," *RCA Rev.*, vol. 3, p. 409–417; April, (1939).

[2] H. E. Kallman, "The gradation of television pictures," *Electronics*, vol. 12, p. 25; December, (1939). (Abstract only.)

[3] Pierre Mertz, "High definition television," *Jour. App. Phys.*, vol. 10, pp. 443–446; July, (1939).

[4] Manfred von Ardenne, "The problem of stereoscopic television," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, p. 26; January, (1939).

[5] A. B. DuMont, "Design problems in television systems and receivers," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 66–74; July, (1939).

[6] R. L. Campbell, "Flexibility in television systems and automatic synchronizing of television receivers," Proc. I.R.E., vol. 28, p. 45; January, (1940). (Abstract only.)

[7] A. V. Bedford and G. O. Fredendall, "Transient response of multistage video-frequency amplifiers," Proc. I.R.E., vol. 27, pp. 277–284; April, (1939).

[8] H. A. Wheeler, "Wide-band amplifiers for television," Proc. I.R.E., vol. 27, pp. 429–438; July, (1939).

[9] J. M. Hollywood, "Single-sideband filter theory with television applications," Proc. I.R.E., vol. 27, pp. 457–472; July, (1939).

[10] L. S. Nergaard, "A theoretical analysis of single-sideband operation of television transmitters," Proc. I.R.E , vol. 27, pp. 666–677; October, (1939).

[11] J. F. Wentz, "Measuring transmission speed of the coaxial cable," *Bell Lab. Rec.*, vol. 17, pp. 309–313; June, (1939).

[12] P. A. Stromberg, "Nonlinear distortions in television," *Izvestiya Electroprom. Slab. Toka*, no. 2, pp. 50–58; February, (1939).

[13] Stanford Goldman, "Television detail and selective-sideband transmission," Proc. I.R.E., vol. 27, pp. 725–732; November, (1939).

[14] H. A. Wheeler, "The interpretation of amplitude and phase distortion in terms of paired echoes," Proc. I.R.E., vol. 27, pp. 359–385; June, (1939).

[15] R. Urtel, "Remarks on single-sideband transmission in television," *Telefunken*, vol. 20, pp. 80–83; July, (1939).

[16] "Television systems standards," *R.M.A. Eng.*, vol. 3, p. 14; May, (1939); vol. 4, p. 24; November, (1939).

[17] "First report of Television Committee," Federal Communications Commission, May 22, 1939.

[18] "Second report of Television Committee," Federal Communications Commission, November 15, 1939.

Program Service

In the New York area one public program transmission averaged approximately 12 hours per week of entertainment features plus a somewhat greater number of hours of test-pattern transmission.

Much work was done on the development of program-production technique,[19–22] and a systematic study of audience reaction to individual programs is being made. The programs included film presentations, live-talent, studio production, and events such as football games, boxing matches, etc., televised outside the studio and relayed to the main transmitter for broadcasting. In addition to the regular program service in New York City, several other stations in various parts of the United States were active in carrying on technical experiments and in developing program-transmission technique.

Prior to the outbreak of the war the television public service in Great Britain was making substantial progress. Program transmissions had been increased to 21 hours a week, and a second studio and a second mobile unit for outside pickups had been put in service.

Remote and Relay Operation

Programs originating in different parts of New York City somewhat over a mile from the transmitter were sent over ordinary telephone cables equipped with special equalizers and amplifiers.[23]

The problem of phase and amplitude distortion in the New York-Philadelphia coaxial cable was described further,[11] and work was started to extend the frequency range of the cable to allow transmission of signals up to 3 megacycles. Direct reception for rebroadcast purposes was accomplished over a distance of 129 miles from New York to the Albany-Schenectady capital districts.

The German television cable network was extended still further during the year, and plans were published and studies made for adapting it to transmission of signals according to the German 441-line standards.[24,25]

Public Demonstrations—Fairs

Public demonstrations of television systems in operation were featured by several exhibitors at the Golden Gate Exposition and New York World's Fair.[26] Numerous other public demonstrations were given in this country, South America, and Europe.[27,28]

TRANSMITTERS

Development of a new camera tube was announced.[29] This uses a low-velocity electron scanning beam and has been used with improved results under adverse light conditions for program transmissions from the Empire State Building in New York. Reports were made on camera pickup tubes showing attention to this phase of television.[30–33]

A new type portable equipment in suitcase form was developed, manufactured, and put into service in the New York and Los Angeles areas for picking up programs remote from the studios. Some of the cameras for this service use a small iconoscope to make possible a small and lightweight unit.

A continuous-type film scanner and associated equipment was put in operation.[34] Water-cooled high-pressure mercury-vapor lamps were used for television-studio lighting.

In addition to transmitters in scheduled program operation at the end of the year, a number of others were under construction or in experimental operation in several parts of the United States.

Among these were a transmitter utilizing 625 lines at 15 frames per second[35,36] and one in which the vestigial-sideband characteristic was obtained at a low power level.

Antenna improvements were directed toward uniform impedance over the desired band, directivity toward the horizon in the vertical plane, and arrangements suitable for installation on the small space available on top of tall buildings. The antennas on the Empire State[37] and on the Chrysler Buildings in New York are of this type. A "cubical type" of antenna for television transmission was described.[38,39]

[19] W. C. Eddy, "Television lighting," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 41; July, (1939).

[20] A. W. Protzman, "Television studio technic," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 26; July, (1939).

[21] H. R. Lubcke, "An introduction to television production," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 54; July, (1939).

[22] W. C. Eddy, "Miniature staging," *Communications*, vol. 19, p. 22; April, (1939).

[23] C. L. Weis, Jr., "Television transmission over telephone cables," *Bell Lab. Rec.*, vol. 19, pp. 34–37; October, (1939).

[24] F. Strecker, "Telephone, facsimile, and television transmission over wires," *Elek. Tech. Zeit.*, vol. 60, p. 214; February 23, (1939).

[25] A. Köpping, "Problems in transmission of wide-frequency bands over wires," *Fernsehen und Tonfilm*, no. 2, pp. 9–12; February (1939).

[26] D. H. Castle, "A television demonstration system for the New York World's Fair," *RCA Rev.*, vol. 4, pp. 6–13; July, (1939).

[27] "Traveling television exhibit," *Teleg.- Fern.- und Funk-Tech.* vol. 28, p. 288; July, (1939).

[28] F. Schröter, "Two-way television technique," *Telefunken*, vol. 20, pp. 30–50; July, (1939).

[29] Albert Rose and Harley Iams, "Television pickup tubes using low-velocity electron-beam scanning," PROC. I.R.E., vol. 27, pp. 547–555; September, (1939).

[30] H. A. Finke, "A television pickup tube," PROC. I.R.E., vol. 27, pp. 144–147; February, (1939).

[31] R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of the iconoscope," PROC. I.R.E., vol. 27, pp. 535–540; September, (1939).

[32] Harley Iams, G. A. Morton, and V. K. Zworykin, "The image iconoscope," PROC. I.R.E., vol. 27, pp. 541–547; September, (1939).

[33] C. C. Larson and B. C. Gardner, "The image dissector," *Electronics*, vol. 12, pp. 24–27, 50; October, (1939).

[34] P. C. Goldmark, "A continuous type television scanner," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 12–25; July, (1939).

[35] R. L. Campbell, "Television control equipment for film transmission," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 677; December, 1939).

[36] "Synchronizing-signal generator," PROC. I.R.E., vol. 27, pp. ii, iv; August, (1939).

[37] N. E. Lindenblad, "Television transmitting antenna for Empire State Building," *RCA Rev.* vol. 3, pp. 387–408; April, (1939).

[38] "Cubical antenna," *Gen. Elec. Rev.*, vol. 42, p. 225; May, (1939).

[39] J. Labus, "Compensation of antenna reaction for television transmitters," *Hochfrequenz. und Elektroakustik*, p. 60; August, (1939).

With the continuance of field tests and the beginning of regular schedules of operation, opportunity was available for further propagation studies pertinent to television.[40] The field strengths of television signals from England, France, and Germany.[41,42] were measured at points on Long Island and occasional pictures of some technical interest from London obtained.

In Germany cathode-ray-tube spot scanners were investigated for film scanning and for direct scanning.[28,43–45] Dissector tubes using multipliers were used for film scanning.[46,47] For general service the image iconoscope was favored.[48–50] Mechanical synchronizing equipment was put into operation in England and Germany.[46,51] Television equipment was built for a station in Rome.[52]

Receivers

American Receivers

The models offered for sale used pictures tubes varying from 5 to 20 inches in diameter and the prices varied from approximately $200.00 to upwards of $700.00. Both console and table models were introduced. In some cases the picture tube screen was viewed directly; in other cases, with vertical mounting of tube, the screen was viewed through a tilted mirror. Some receivers had both picture and sound reception, while others had picture reception but required a complementary sound broadcast receiver to provide the loud speaker and part of the amplification for the sound signal. Still other models had not only complete picture and sound reception of the television signal but also included an all-wave broadcast receiver. A special television antenna installation was usually necessary for satisfactory reception.

Technical Characteristics

All the receivers offered for sale were of the superheterodyne type. Fixed-tuned station selectors were universally used, with a manual "fine-tuning control." Most receivers followed the Radio Manufacturers Association practice of using 8.25 megacycles for the sound carrier and 12.75 megacycles for the picture carrier. The most sensitive sets were capable of fully modulating the picture tube with an input signal of about 150 microvolts.

Horizontal dipole antennas were employed (generally with a reflector or director dipole) which were connected to the receiver through a low-loss balanced transmission line.[53,54]

Much attention was given to the design[55] of the radio-frequency selector circuits.

Considerable advance was made in increasing the stability of heterodyne oscillators, ultra-high-frequency circuits, and intermediate-frequency transformers by the application of temperature-compensated capacitors and the use of stryrol forms with iron cores.

Much development work was done in the design of suitable picture intermediate-frequency amplifiers. It was found that resistance-loaded wide-band transformers did not give sufficient attenuation at the sound carriers of the signal channel and of the adjacent channel. It was therefore necessary to use at least two band-pass filters with respective elimination points at the two sound carriers in question. Four stages of picture intermediate-frequency amplification were generally used, and considerable use was made of the newly developed high mutual-conductance low-power-drain amplifier tubes.[56] Both half-wave and push-pull detectors were to be found.

Wide-band (up to 4 megacycles) video-frequency amplifiers were used with linear phase-shift characteristics. A great deal of research was directed toward the development of these amplifiers[57] and the theory[7,8,58] of various types of distortion introduced both in the video-frequency stages and picture intermediate-frequency stages. In particular, it was found that small amounts of either amplitude or phase distortion caused a pair of apparent echoes, one preceding and one following the signal.

Automatic brightness control of the picture tube to restore the direct-current component of the signal was generally used.

[40] K. G. MacLean and G. S. Wickizer, "Notes on the random fading of 50-megacycle signals over nonoptical paths," Proc. I.R.E., vol. 27, pp. 501–506; August, (1939).

[41] D. R. Goddard, "Observations on sky-wave transmission on frequencies above 40 megacycles," Proc. I.R.E., vol. 27, pp. 12–15; January, (1939); *RCA Rev.*, vol. 3, pp. 309–315; January, (1939).

[42] D. R. Goddard, "Transatlantic reception of London television signals," Proc. I.R.E., vol. 27, pp. 692–695; November, (1939).

[43] A. Gehrtz, "Development and present status of the television technique," *Europäischer Fernsprechidienst*, no. 51, p. 18; March, (1939).

[44] Kurt Bruckersteinkuhl, "Afterglow of luminescent substances and its influence on the cathode-ray tube spot scanner," *Fernseh A. G.*, vol. 1, p. 179; August, (1939).

[45] A. Schleede and B. Bartels, "On the development of fluorescent screen for cathode-ray tubes," *Telefunken*, no. 81, pp. 100–108; July, (1939).

[46] R. Moller and G. Schubert, "The development of Fernseh television receivers and pickup devices during the year 1939," *Fernseh A. G.*, vol. 1, p. 153–161; August, (1939).

[47] Werner Hartmann, "The image dissector," *Fernseh A. G.*, vol. 1, p. 130; July, (1939).

[48] R. Behne, "The development of the storage tube," *Fernseh A. G.*, vol. 1, p. 134; July, (1939).

[49] H. Knoblauch and G. W. Kluge, "The image-amplifier storage tube," *Telefunken*, no. 81, p. 51–54; July, (1939).

[50] H. Sallow, "Storage-type camera tubes with semiconducting dielectric," *Fernsehen und Tonfilm*, no. 1, pp. 1–4; January, (1939).

[51] G. Wikkenhauser, "Synchronization of Scophony television receivers," Proc. I.R.E., vol. 27, pp. 492–496; August, (1939).

[52] Johannes Schunack, "Television pickup equipment for station EIAR in Rome," *Fernseh A. G.*, vol. 1, pp. 102–107; April, (1939).

[53] P. S. Carter, "Simple television antennas," *RCA Rev.*, vol. 4, pp. 168–185; October, (1939).

[54] S. Goldman, "Dipole arrays as television receiving antennas," *R.M.A. Eng.*, vol. 4, pp. 2–8; November, (1939).

[55] G. Mountjoy, "Television signal frequency circuit considerations," *RCA Rev.*, vol. 4, pp. 204–230; October, (1939).

[56] A. P. Kauzmann, "New television amplifier receiving tubes," *RCA Rev.*, vol. 3, pp. 271–289; January, (1939).

[57] S. W. Seeley and C. N. Kimball, "Analysis and design of video amplifiers, Part II," *RCA Rev.*, vol. 3, pp. 290–308; January, (1939).

[58] H. Kallman, "Transient response in television," Proc. I.R.E. vol. 27, p. 613; September, (1939). (Summary only.)

For scanning, saw-tooth current or voltage generators generally employed some form of synchronizable oscillator followed by a wave-form amplifier. Such amplifiers usually contained adjustable wave-shape circuits (linearity controls). For magnetic scanning a damping diode was frequently employed to increase the range of linearity of the horizontal scanning amplifier and a special output tube, the 6AL6G with an 8000-volt breakdown potential, was developed to withstand the high impulse voltages which occur.

All picture tubes used had white screens, and their screen diameters ranged from 5 to 20 inches.[6] Electric and magnetic scanning and focusing were used. It has been found that halation is the most harmful factor in damaging the contrast in picture tubes.[59]

The highest anode voltage used in home receivers was 8000 volts and the lowest about 2000 volts. Receivers were made which would perform satisfactorily on a 50-cycle power-line voltage while receiving a Radio Manufacturers Association standard (60-field) picture.

Those receiver models which required a complementary broadcast receiver for their sound, generally supplied an audio-frequency signal from the television sound detector to the audio-frequency amplifier of the broadcast receiver. However, there also were receivers designed to radiate the sound intermediate frequency and have it picked up in the antenna of a broadcast receiver.

Receivers for picking up television signals from remote-pickup transmitters operating above 300 megacycles were placed in operation.

Safety Precautions

Elaborate precautions were taken to make receivers safe. On the electrical side, cabinet-back interlocks were generally used which operated by breaking the line circuit. In addition to this, a high resistance in the anode lead of the high-voltage rectifier was frequently used to reduce the high voltage in case of an accidential low-resistance load. In connection with the question of picture-tube implosion, bulb shape was considered, safety glass was usually used in front of the screen, and the body of the tube was surrounded by a metal or paper shield.

Receiver Controls

Controls requiring only an initial adjustment during installation and hence segregated on the chassis, generally included picture width, picture height, horizontal centering, vertical centering, horizontal linearity, vertical linearity, and astigmatic control. Controls for the operators' use generally included station selector, fine-tuning control, volume control, tone control, contrast control, brightness control, and focus.

The horizontal and vertical hold controls were in some cases on the panel and in other cases segregated.

A method of aligning television receivers in production was described in which test signals are supplied from a central source.[60]

Interference in a signal caused by other television transmitters operated at the same frequency was the subject of some study. One investigator[61] concluded that the interfering signal is troublesome unless it is 40 decibels below the level of the desired signal. The Subcommittee on Television Allocations of the Radio Manufacturers Association used 46 decibels for this figure. To reduce the effect of ignition noise, peak limiters were employed. Interference from diathermy apparatus has been objectionable.

Foreign Developments

New and improved models of television receivers were offered for sale in Great Britain. A simple highly directional tilted-wire television antenna was used.[62] High-mutual-conductance secondary-emission tubes were tried out with success, and a careful study of the high-frequency circuits of a television receiver was made.[63] A system for obtaining large pictures in television reception by electromechanical means was described in detail,[54,64–66] and another system using electronic projection tubes was demonstrated.[67]

In Germany, a series of home receivers was developed, both for direct viewing and for projection.[46] Magnetic deflection and focusing with wide-angle tubes were generally used.[68–71] In particular, a standard television receiver was developed as a cooperative effort among the five largest German tele-

[59] R. R. Law, "Contrast in kinescopes," PROC. I.R.E., vol. 27, pp. 511–523; August, (1939).

[60] L. J. Hartley, "Production alignment apparatus for television receivers," PROC. I.R.E., vol. 27, p. 612; September, (1939). (Summary only.)

[61] C. N. Smyth, "Continuous-wave interference with television reception," PROC. I.R.E., vol. 27, p. 415, June, (1939). (Summary only.)

[62] "New television aerial," *Wireless World*, vol. 35, p. 206; August 31, (1939).

[63] M. J. O. Strutt, "High frequency mixing and detection stages of television receivers," *Wireless Eng.*, vol. 16, pp. 174–187; April, (1939).

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[70] Theodor Mulert and Herbert Bahring, "Transformer sweep circuit generators," *Fernseh A. G.*, vol. 1, pp. 82–88; April, (1939).

[71] F. Rudert, "Points in design of home receivers," *Fernsehen und Tonfilm*, no. 5, pp, 33–36; May, (1939).

vision firms.[72–81] The picture tube used in this receiver had a flat rectangular face. Other picture-tube developments were also reported.

This report was prepared by the 1939 Technical Committee on Television of the Institute of Radio Engineers, the personnel of which follows:

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[75] T. Mulert and R. Urtel, "Beam deflection and high-voltage generator in the standard television receiver E1," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, p. 257–264; July, (1939).
[76] Henning Knoblauch and Erich Schwartz, "The picture tube in the standard television receiver," *Teleg.- Fern.- und Funk-Tech.*, vol., 28, pp. 264–269; July, (1939).
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[80] H. O. Roosenstein, "On the common reception in television," *Telefunken*, vol. 20, pp. 25–29; July, (1939).
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PART VII—FACSIMILE*

Broadcast Facsimile—Point-to-Point Facsimile (Radio, Wire and Cable)

Broadcast Facsimile

In the general field of experimental facsimile broadcasting the rapid expansion of transmission on standard broadcast channels which occurred in 1938 slowed down. Progress in the field during 1939 came chiefly in increased operation of existing equipment by the broadcasters with resulting experience in the techniques and possibilities of the system. There was a growing tendency to utilize ultra-high-frequency channels rather than in the broadcast band during the night. Of the 25 stations licensed or under construction near the close of 1939, almost two thirds were in the ultra-high-frequency band.

The facilities employed by the stations were essentially the same as in the previous year. These were described in the Committee's report for 1938.

In some systems, which were changed from broadcast-band to ultra-high-frequency operation, crystal-controlled adaptors were used in the receivers.

Higher speeds of operation and larger copy sizes were introduced in the last year.[1] Machines were made available for $8\frac{1}{2}$- and $10\frac{1}{2}$-inch paper width, fed at the rate of 2 inches per minute. These scan at 100 lines per inch. The trend is running toward machines wasting a minimum of time between scanning strokes. Automatic synchronization and automatic framing were further developed to permit operation on any source of electric power. Three principal recording processes continued to be used, namely damp-electrolytic, dry-electric, and carbon paper.

Experimental transmissions were carried out successfully using frequency modulation on approximately 40 megacycles.

Some demonstrations of broadcast facsimile were attractions at the New York World's Fair.

In Italy some study was made of facsimile broadcasting with machines patterned after a make used in the United States.[2]

Point-to-Point (Radio)

An improved system using subcarrier frequency modulation[3] was introduced commercially on the New York-London circuit on May 15 and on the New York-Buenos Aires circuit on December 14. Picture-controlled frequency modulation of the audio-frequency subcarrier is employed over standard radio-station equipment normally used for point-to-point program or telephone service. By means of this system distortion encountered on the over-all circuit is substantially minimized under even adverse conditions and linear operation is made possible. Handling speeds have been tripled, along with a noticeable improvement in recorded copy.

For mobile use a duplex type of facsimile unit for handling two-way simultaneous communication on the same channel is now available.[4,5] It contains two drums, one for transmission, the other for reception, using message blanks 8 by 7 inches. Due to its small size and light weight, it may be used between mobile stations in cars, trucks, planes, or other moving vehicles or between these and fixed stations. It is thus suitable for police and military services. Copy may be transmitted at a speed of 8 square inches per minute with a definition of 100 lines to the inch. Synchronized operation is entirely automatic.

* Decimal classification: R583.
[1] "Finch high speed facsimile system," *Electronics*, vol. 12, pp. 61–62; May, (1939).
[2] "Tests on radio facsimile transmission in Italy," *Radio e Televisione*, vol. 3, pp. 309–316; March, (1939).
[3] R. E. Mathes and J. N. Whitaker, "Radio facsimile by subcarrier frequency modulation," *RCA Rev.*, vol. 4, pp. 131–153; October, (1939).
[4] Henry Roberts, "Finch radio facsimile," *Aero Digest*, vol. 36, p. 163; January, (1939).
[5] Robert D. Potter, "Two way facsimile unit developed for aviation," *Science News Letters*, vol. 36, p. 341; November 25, (1939).

French facsimile equipment was installed at the New York World's Fair operating by radio with Paris.[6]

In Canada, a direct radio-facsimile service was established between Montreal and London in connection with the visit of Their Majesties, the King and Queen of England, to Canada and the United States.[7]

Point-to-Point (Wire and Cable)

The use of wire telephotography for news-picture transmission in the United States is increasing. The year 1939 was marked by the elaborate coverage by wire-news-picture service of the visit of the King and Queen.

The wire transmission is carried out, as reported last year, over both a specially engineered private-line network connected between fixed points, and over regular long-distance message-toll circuits. Portable equipment is frequently used.

Studies, both theoretical and experimental, were carried out to check the effectiveness of using vestigial-sideband (or nearly single-sideband) transmission of telephotograph signals. A considerable improvement was reported over double-sideband transmission using the same total available frequency band width.[8] In Germany a study was carried out of direct positive-picture reception, with apparently satisfactory results.[9]

High-quality picture transmission by ocean cable was initiated between London and New York early in the year. The system makes use of the high-speed loaded submarine-telegraph cable from England via Newfoundland to New York. The transmission system is new in ocean-cable practice, with 4 completely electronic repeaters, each of which includes extensive electrical networks to compensate for cable distortion and minimize effects of extraneous interference. The system is noncarrier, utilizing the band from substantially zero frequency to 150 cycles per second. The transmission speed is about 2 square inches per minute. The various news-picture organizations have made extensive use of the new service.

[6] "Proposed new facsimile service to New York Fair," *U. S. Foreign Comm. News*, vol. 13, pp. 148–149; August 11, (1939).

[7] "Canadian Marconi inaugurates trans-Atlantic radio facsimile service," *Tel. and Tel. Age*, no. 1261, p. 133; June, (1939).

[8] H. Nyquist and K. W. Pfleger, "Effect of the quadrature component in single sideband transmission," *Bell Sys. Tech. Jour.*, vol. 19, pp. 63–73; January, (1940).

[9] W. Heintze and H. Schoenfeld, "Reception of positive pictures in telephotographic transmissions," *Elek.-Nach. Tech.*, vol. 16, pp. 87–91; April, (1939).

The application of facsimile to point-to-point message service expanded. In addition to the commercial extension of the facsimile systems and apparatus, a new type of automatic facsimile scanner was developed. This transmitter is designed especially to provide a convenient and rapid method for the collection of telegrams and their delivery to a central office. This machine, known as the automatic telegraph, is only slightly larger than a mail box, and is installed in branch offices, customers' offices, office buildings, hotel lobbies, etc.

The telegram is placed in the machine by the customer or attendant in much the same manner as a letter is dropped into a mail box. At the central office an automatic recorder is used to record the telegram on a dry electrically sensitive recording paper.

In the extension of facsimile to commercial service, this automatic-telegraph method was included in the conversion of a large branch office in New York. A number of these transmitters were also employed at both the New York and San Francisco World's Fairs to handle telegrams originating at these points.

Experiments in facsimile message transmission were also conducted with equipment of the type described above under broadcast facsimile. About 250,000 words of news bulletins were transmitted on this basis by wire from a point in Toronto and received at the Canadian National Exposition. The recorder produced black-and-white copy, using an electrolytic process on slightly moistened paper.

An extensive network of public and private stations was developed in Europe.[10–15]

This report was prepared by the 1939 Technical Committee on Facsimile of the Institute of Radio Engineers, the personnel of which follows:

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[10] "Status of telephotographic connections in Europe," *Siemens Zeit.*, vol. 19, pp. 47–48; January, (1939).

[11] "Introduction of facsimile telegraph letters," *E.F.D.*, p. 216; July, (1939).

[12] "Progress in telephotography," *Elec. Rev.*, (London), vol. 125. p. 433; September 29, (1939).

[13] O. Lemke, "Telephotography for the general public," *Telegraphen Praxis*, vol. 19, pp. 133–135; May 13, (1939).

[14] "Russia makes marked progress in facsimile transmission," *Tel. and Tel. Age*, no. 1267, p. 275; December, (1939).

[15] "Pictures by wire," *Electronics*, vol. 12, pp. 13, 14, 15, 90, 91; September; (1939).